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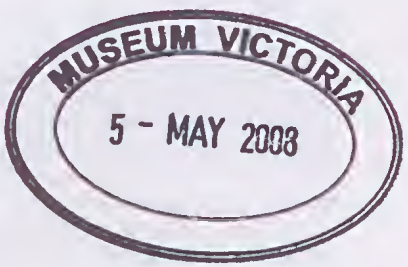

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STEMS WITH ATTACHED *DICROIDIUM* LEAVES FROM THE IPSWICH COAL MEASURES, QUEENSLAND, AUSTRALIA.

ANDERSON, H.M., HOLMES, W.B.KEITH & FITNESS, L.A.

Anderson, H.M., Holmes, W.B.Keith & Fitness, L.A. 2008 04 30: Stems with attached *Dicroidium* leaves from the Ipswich Coal Measures, Queensland, Australia. *Memoirs of the Queensland Museum* **52**(2): 1-12. Brisbane. ISSN 0079-8835.

A single large block of massive siltstone with bands of medium to fine sandstone from the Late Triassic Blackstone Formation of the Ipswich Coal Measures of Queensland has revealed three stems each bearing fascicles of *Dicroidium elongatum* leaves. Two stems are preserved parallel to the bedding plane and the third is a vertically compressed and coalified stem passing at c. 45° through the matrix. The specimens show a single leaf or fascicles of from two to four leaves attached to protuberances or short shoots arranged spirally up the stems. This is the first occurrence in the fossil record of the multiple attachment of leaves and the growth habit of the plants in the ubiquitous Gondwana genus *Dicroidium*.
❒ *Triassic, Ipswich, fossil flora, Dicroidium leaves, stem attachment.*

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DICROIDIUM – THE ENIGMATIC GONDWANA TRIASSIC PLANT

The forked leaves ascribed to *Dicroidium* have been known since Morris (1845) described the first specimens from the Triassic of Tasmania. Gothan (1912) established the new genus *Dicroidium* to accommodate certain *Thinnfeldia*-like fronds with a forking rachis from Gondwana. On the basis of close association and similarities of cuticles Thomas (1933) affiliated the male pollen-bearing organ *Pteruchus* and the female ovulate structure *Umkomasia* with *Dicroidium*. These fertile structures and *Dicroidium* have been reviewed by Anderson & Anderson (2003) and classified as gymnosperms in the Class Ginkgoopsida, Order Umkomasiales and the Family Umkomasiaceae that is restricted to the Triassic.

Dicroidium leaves range in form from simple to pinnate to bipinnate and tripinnate and have been recorded from all Gondwana continents. They are common to dominant in many Gondwana Triassic fossil plant assemblages. Anderson & Anderson (2003) noted that *Dicroidium* was present in 75 of their 100 taphocoenoses (TCs = assemblages) from the Molteno Formation of South Africa. In 54 of these TCs *Dicroidium* was mono-dominant to co-dominant. In the Middle Triassic Benolong Flora from near Dubbo NSW leaves of *Dicroidium* and the gingkoalean *Sphenobaiera* formed the bulk of the preserved plant material (Holmes, 1982). *Dicroidium* leaves were recorded as the most commonly preserved fossils in the rich and diverse Middle Triassic Nymboida Flora from the Nymboida Coal Measures of northern NSW (Holmes & Anderson, 2005). In the open east coal mines at Leigh Creek in South Australia thin beds of 'paper coal' are composed of *Dicroidium zuberi* cuticles (K. Holmes pers. obs. 1997). Rich assemblages from South America have been described by Artabe (1985) and Gnaedinger & Herbst (1998; 2001). While the leaves of *Dicroidium* are abundant and widespread throughout Triassic Gondwana (as reviewed by Anderson & Anderson, 2003) clues to the habit of the plant that bore the leaves are limited.

Petriella (1978) reconstrueted *Dicroidium* as a palmiform tree with a substantial trunk to 10m high, while various other authors have speculated that *Dicroidium* ranged from shrubs to tall trees (Retallack, 1980; Anderson & Anderson, 1982; Anderson et. al., 1998; Anderson & Anderson, 2003) or was a large tree (Taylor, 1996). The whole-plant reconstruction by Retallack & Dilcher (1988, fig.10) showed a tall deciduous forest tree in a seasonally wet lowland.

The first convincing specimen of leaf attachment was of two leaves attached apically on an elongated stem from the Molteno Formation of South Africa (Anderson & Anderson, 1983, Pl. 88, fig. 1). Another incomplete specimen (Anderson & Anderson, 1983, Pl.88, fig. 2)

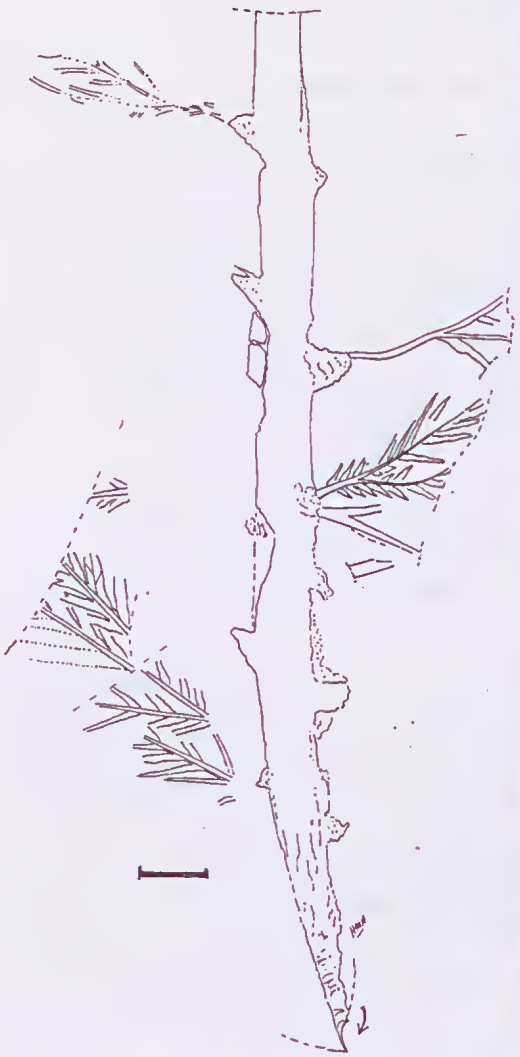


FIG. 1. Line-drawing (R1) of *Dicroidium elongatum* stem and leaves based on part and counterparts QMF52275C,D,E. Scale = 10mm

FIG. 2. Stem with *Dicroidium elongatum* leaves attached. QMF52275C, counterpart of QMF52275D. Scale = 10mm

suggested that the leaves were attached in a fascicled manner to a stem. The reconstruction by Anderson and Anderson (2003, p. 257, text fig.5) was based on these specimens.

Archangelsky (1968) argued a case for the affiliation of silicified logs of *Rhexoxylon* and *Dicroidium* leaves. During a Mesozoic Terrestrial Ecosystems Congress Field Trip to view exposures of the Ischigualasto Formation in southern Argentina WBKH and HMA observed shale beds packed with *Dicroidium* leaves in close association with large petrified logs of *Rhexoxylon* but with no evidence of attachment. This was probably the same occurrence as that described by Archangelsky. *Rhexoxylon* has also been recorded in South Africa in the "Red Beds" now termed the Elliot Formation (Walton, 1923) and usually dated as Jurassic which would be well beyond the time range of *Dicroidium*. Meyer-Berthaud et al. (1993) described permineralised twigs from Antarctica as *Kykloxylon* and suggested that the stems bore *Dicroidium fremouwensis* leaves as described by Pigg (1990), but the leaves have not been found in organic connection. In a

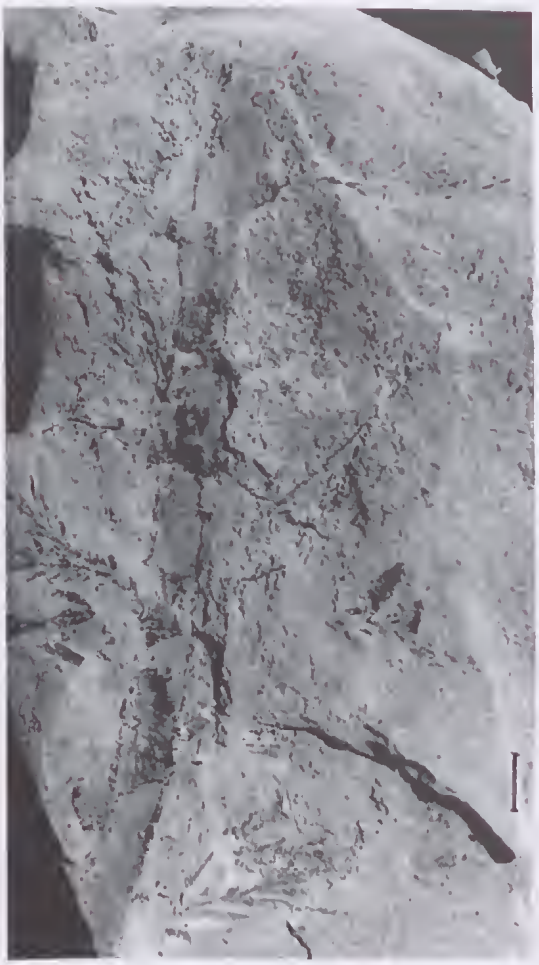


FIG. 3. Stem with *Dicroidium elongatum* leaves attached. QMF52275D. Scale = 10mm.

paper deseribing *Umkomasia uniramia* Axsmith et al. (2000, figs 6, 8) illustrated a *Dicroidium odontopteroides* leaf apparently eontiguous with, or overlain by, a stem of a plant with long and short shoot morphology. By analogy with extant plants bearing long and short shoot morphology (e.g. *Gingko biloba*) it would be unlikely in the extreme for a plant with this growth morphology to bear a leaf on the long shoot section of a stem subsequent to the formation of well-developed short shoots. On the illustrated Antaretie speeimen even the short shoots are in a leafless state although still bearing the ovulate fructifications. The elose association of the *Dicroidium* leaf with the stem bearing short shoots suggests an affiliation but this is not exelusive as other leaves (e.g. *Heidiphyllum*, *Taeniopteris*) are reported as being present in the same deposit. Cúneo et al. (2003) deseribed a

FIG. 4. Partial reconstruction (R3) of *Dicroidium elongatum* stem with some leaves. QMF52275C, D, E. Scale = 10mm

Triassie in situ forest in the Fremouw Formation of Antaretiea eonsisting of 99 petrified standing stumps that indieated a forest density of e. 270 trees/heetare. The wood eorresponds with that deseribed by Del Fueyo et al. (1995) as *Jeffersonioxylon*. Based on the diameter (60cm) of the largest stump and the maximum number of growth rings (86) it was estimated that the forest may have reaehed a height of more than 30m, with an average eanopy height between 14 and 25m. The sediments assoeiated with the stumps eontain mats of *Dicroidium* leaves. While there is no evidence of attachment their exelusive oeeurenee indieates that the *Dicroidium* leaves were produeed by the trees now preserved as the in situ stumps.

NEW MATERIAL OF STEMS WITH ATTACHED LEAVES

In 2005 during a plant fossil eolleeting trip in the Ipswich Distriet, LAF reeovered some plant fossils from a large block of grey siltstone with paler thin bands generally less than 3.5mm thiek of eross-bedded medium to fine sandstone. The

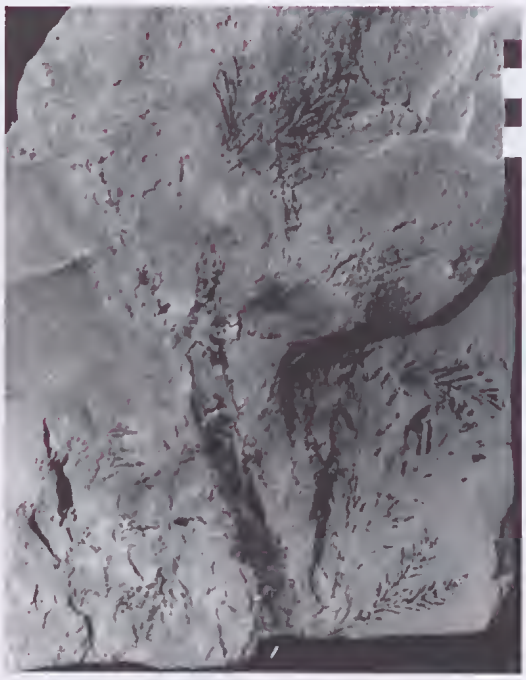


FIG. 5. Branching stem with *Dicroidium elongatum* leaves attached. QMF52275B. Scale = 10mm.

FIG. 6. A fascicle comprising a large and small leaf of *Dicroidium elongatum* attached to the stem on right side. QMF52275A, counterpart QMF52275B. Scale = 10mm.

nature of the block indicates the sediments were deposited during gentle current activity from periodic overbank flooding events. The block as found was bounded on two sides by oblique joint fractures. The collecting site was in the old Dinmore Quarry near Ipswich (Pattemore, 1998) in heaps of overburden dumped from the nearby, now worked-out, open-east mines that exploited the coal seams in the Late Triassic Blackstone Formation of the Ipswich Coal Measures, south-east Queensland (Playford & Rigby, 1988). The stratigraphic horizon and exact source of the specimens in this overburden material is not known.

The initial specimens were two individual horizontal stems each bearing fascicles of attached *Dicroidium elongatum* leaves together with the counterparts. Recognising the importance of the find, further material was later collected from the original shattered block including some radiating groups of leaves and two large vertically adjacent fragments showing a semi-vertical coalified stem and indications of fascicles of leaves radiating into the matrix. By now the remains of original large block were in fragments and dispersed. The specimens illustrated and described were all recovered from the single original block.

The collection comprises two horizontal stems with attached fascicles of *Dicroidium elongatum* leaves and blocks showing a coalified semi-vertical branched stem with fascicles of leaves radiating into successive layers of the matrix. Leaves and horizontal stems are preserved as compressed carbonaceous material or have been replaced or stained with iron oxide. A few fragments of *Dicroidium odontopteroides* leaves are scattered through the matrix and as a layer in a lower coarser sandstone band. We have endeavoured to reassemble the whole block from the collected material, but with only partial success as some of the intermediate fragments are missing. Minimal chipping of specimens has been carried out. Further detailed disengagement of some of the partially hidden leaf fascicles may reveal additional information. The total collection represented by 17 pieces has been allocated the single Queensland Museum Fossil Number QMF52275 with the individual pieces identified with upper case letter suffixes, as QMF52275A to QMF52275Q (to avoid confusion, letters I, L and O have not been used).

FIG. 7. Line drawing (R2) of branching stem with attached *Dicroidium elongatum* leaves; based on part QMF52275A and counterpart QMF52275B. Scale = 10mm.

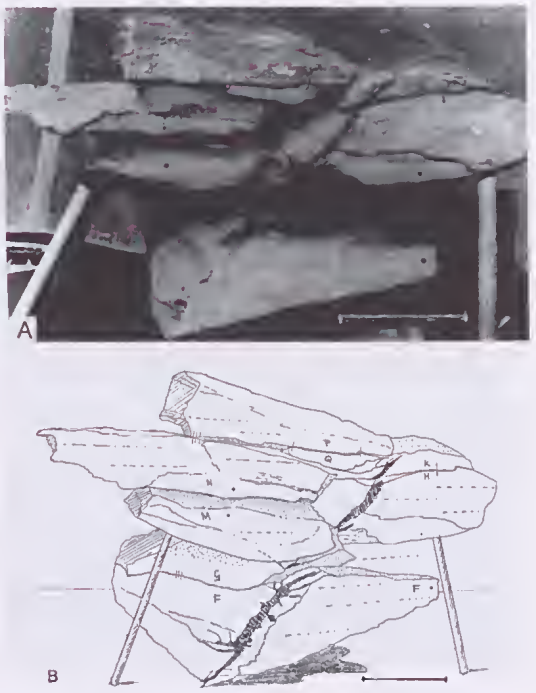


FIG. 8. *Dicroidium elongatum* leaf fascicle. A, QMF52275H and J upper surface; B, Counterpart of fascicle in Fig. 8A, (portion only), QMF52275K lower surface. Scale = 10mm.

The collection is housed in the Palaeontological Department of the Queensland Museum, Brisbane.

THE LEAF-BEARING STEMS

Two separate horizontally compressed stems are preserved with attached fascicles of *Dicroidium elongatum* leaves. The stem and its counterpart (Figs 1–4) is c. 160mm long and 10mm wide and shows individual leaves and two fascicles of leaves attached. For most of its length the stem is compressed parallel to the bedding plain but basally the stem curves downwards into the sediment. The second specimen and its counterpart (Figs 5–7) is a portion of a woody stem 180mm long and c. 14mm wide. A lateral branch, c. 6mm wide is attached to the main stem at c. 45°. A fascicle of two leaves is attached at c. 45° near the base and another leaf fascicle at a high angle at 65mm along the stem. Further fragments of fascicles are aligned in the matrix as though originally attached to the stem.The swollen leaf bases of the attached fascicles and the irregularly spaced protuberances along the stems of both the above specimens probably represent short shoots.

A third compressed and coalified stem with cleat structure is preserved in a semi-vertical position passing upwards through the matrix on the margin of four blocks, for a length of 270mm (Figs 9). Near the base the width is c. 20mm then contracting to 10mm distally. Fascicles of leaves (Figs 8, 10) radiate horizontally into the matrix at close intervals adjacent to the mid to upper section of the stem. Coalified ?roots radiate from the base and up the main stem there is evidence of some lateral branches. A frontal view of the blocks encompassing the main stem is illustrated in Fig. 9. The schematic sketches (Figs 10A, 10B) show the three dimensional placement of leaf fascicles. Figs 11 and 12 are serial depictions of the upper and lower surfaces of the blocks adjacent to the main coalified stem and show the arrangement of leaves preserved horizontally in the matrix. A separate leafless coalified stem c. 0.5mm in diameter passes vertically through the matrix (see Fig. 11, S1). It cannot be established whether the two stems illustrated in Figs 1–7 connect with the semi-vertical stem or are independently preserved fragments. Also a connection between the fascicles

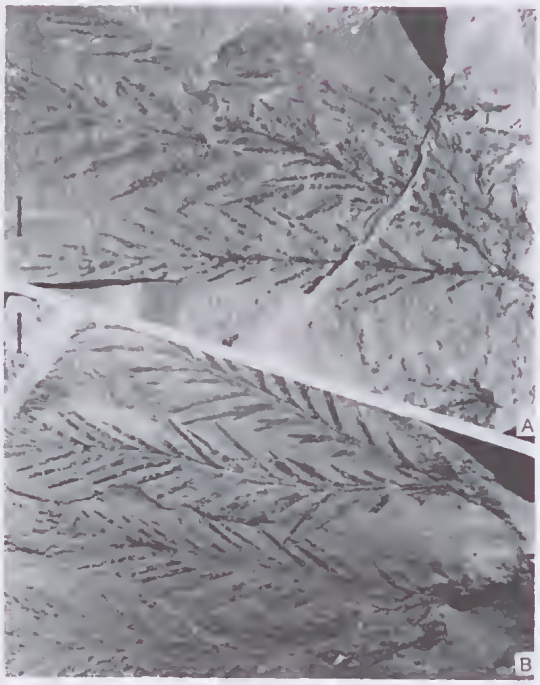


FIG. 9. A, Frontal view of reassembled blocks QMF52275F–Q associated with the semi-vertical stem. Scale = 100mm; B, Schematic sketch of reassembled blocks shown in Fig. 10A. Scale = 100mm.

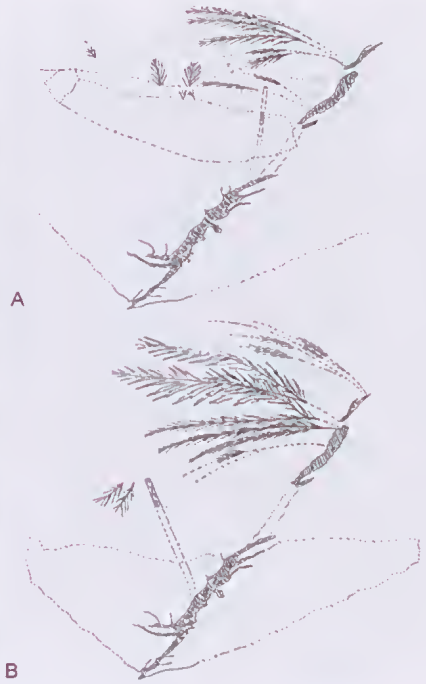


FIG. 10. Partial reconstruction of foliage associated with the semi-vertical stem. A. Based on blocks QMF52275M–Q. B. Based on blocks QMF52275F–K.

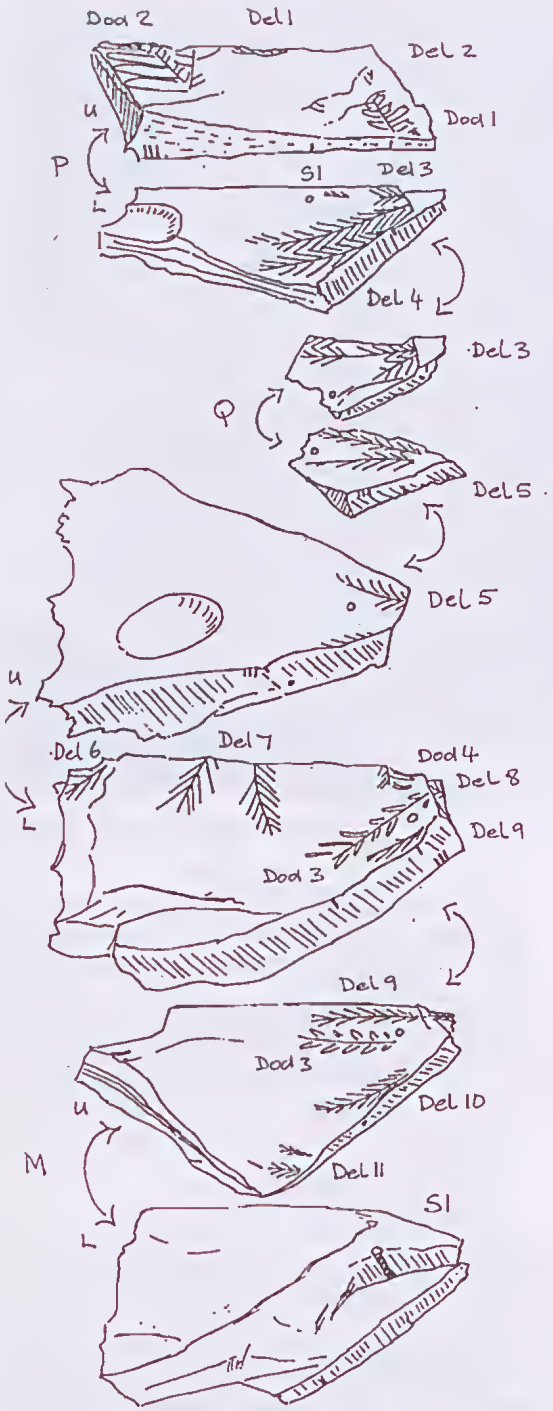
of leaves (QMF52275R) shown in Fig. 13 and any stem is missing.

DICROIDIUM LEAVES AND THEIR ATTACHMENT

The forked leaves from this assemblage while differing greatly in size, are uniformly pinnate to slightly bipinnatifid. They fit well into *Dicroidium elongatum*, a variable morpho-taxon, often with many intergrading forms that have in the past and even to the present, been placed in several genera, species, varieties or formae (Carruthers, 1872; Tenison Woods, 1883; Shirley, 1898; Walkom, 1917; Frenguelli, 1943; Jones & deJersey, 1947; Hill et al., 1965; Retallack, 1977; Holmes, 1982; Anderson & Anderson, 1982; 2003; Artabe, 1985; Gnaedinger & Herbst, 2001; Holmes & Anderson, 2005). Pattemore & Rigby (2005) argued for the retention of the genus *Xylopteris* for this form of leaf based on the presence of a male fructification apparently attached apically to a *Dicroidium elongatum* leaf. We have examined the specimen in the Queensland Museum and consider the leaf and fructification to be two separate entities.

In the present material, leaves are attached in close groups of from one to four to a swelling or protuberance on a slightly tapering and sympodially branching stem. The grouping of several leaves is here regarded as a fascicle but may be a close spiral on a poorly developed short shoot. Previously published illustrations of incomplete groups of *Dicroidium* leaves (e.g. *Trichomanides elongata* of Shirley, 1898, pl.10, fig. 3; also from the Blackstone Formation and *Dicroidium odontopteroides*, Anderson & Anderson, 1982, pl.88, fig. 2) suggest a similar fascicular arrangement. The reconstruction of *D. odontopteroides* by Anderson & Anderson (2003) depicts a fascicle of leaves terminal on an elongated stem.

In our Dinmore material the leaves are variable in length (even in the same fascicle (Figs 6, 7) ranging from 50mm–160mm long. Fascicles comprising mostly three leaves ranging in length from 140–160mm (Figs 8, 10) radiate into the matrix parallel to the bedding plane from the semi-vertical stem. Based on the few attached fascicles the angle of attachment to the stem ranges from 45°–90°. Additional fragments of fascicles are aligned in the matrix in the



Note that slivers of matrix may be missing between some of the slabs.

QMF52275P Upper surface
D.el. 1. Small portion of leaf at block margin.
D.el. 2. Small distal portion of forking leaf in alignment with main stem.
D.od. 1. Fragment of leaf.
D.od. 2. Portion of forked leaf.

QMF52275P Lower surface
Stem 1. Coalified stem vertical through slab (indicated by a circle).
D.el. 3. Forked leaf; base concealed in matrix.
D.el. 4. Distal portion of frond. This leaf and *D.el.* 3. are aligned with main axis and probably from a common base.

QMF52275Q Upper surface
D.el. 3. As above.
D.el. 4. As above but smaller fragment preserved.

QMF52275Q Lower surface
D.el. 5. Forked leaf, base missing; in alignment with main axis.

QMF52275N Upper surface
D.el. 5. As above; smaller fragment of leaf preserved.

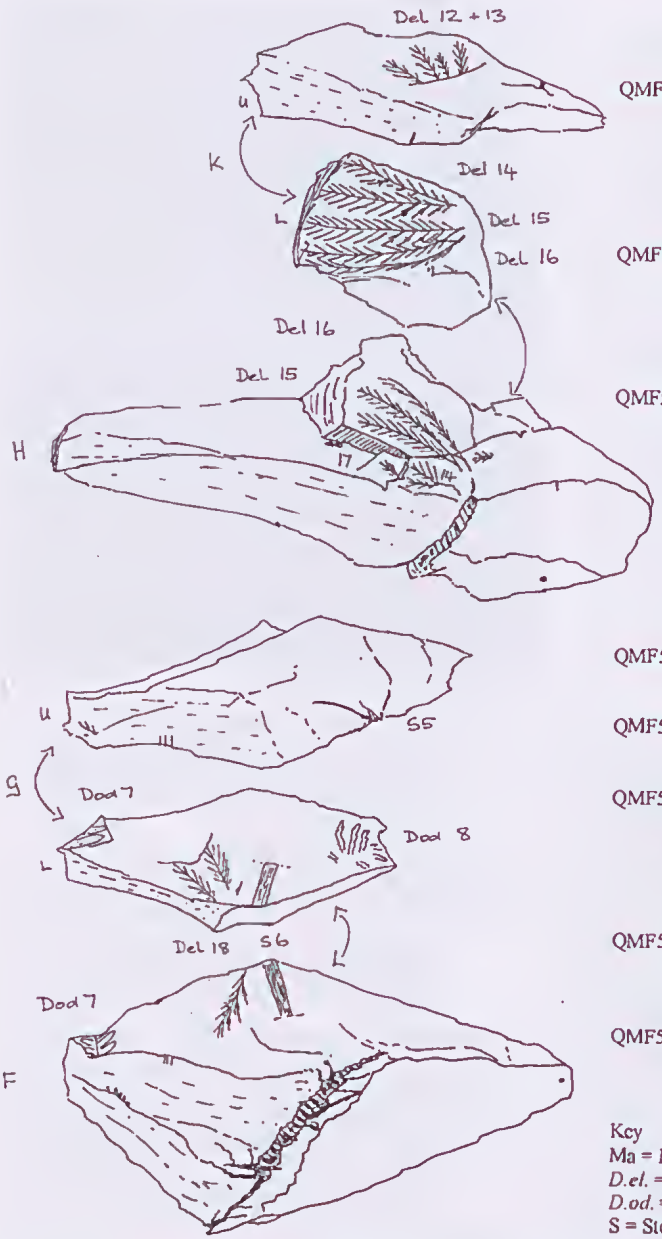
QMF52275N Lower surface
D.el. 6. Small portion of leaf.
D.el. 7. Distal portion of forked leaf.
D.el. 8. Portion of leaf aligned with main axis.
D.el. 9. Portion of leaf aligned with main axis.
D.od. 3. Fragment of leaf.
D.od. 4. Fragment of leaf.
S. 2. Stem aligned with main axis.

QMF52275M Upper surface
D.el. 9. Portion of leaf aligned with main axis; basally passing down through matrix.
D.el. 10. Portion of leaf aligned with main axis.
D.el. 11. Portion of leaf aligned (?) with main axis.
D.od. 3. Fragment of leaf.
S. 2. Stem passing through matrix.

QMF52275M Lower surface
S1. Stem preserved vertically through all slabs and here exposed over a 15mm length with a diameter of 6mm.
S3. Stem exposed on two sections of the slab and aligned with main axis.

Key
S = Stem
D.el. = *Dicroidium elongatum*
D.od. = *Dicroidium odontopteroides*
Figure 9B

FIG. 11. Serial depictions of the upper and lower surfaces of blocks to show position and alignment of the leaves and stem branches associated with semi-vertical axis. Based on blocks QMF52275M–Q.



Note that slivers of matrix may be missing between some of the slabs.

QMF52275K Upper surface
D.el. 12. Distal portion of leaf; aligned with main axis.
D.el. 13. Distal portion of leaf; aligned with main axis.
Both leaves probably attached to a common base.

QMF52275K Lower surface
D.el. 14. An almost complete leaf.
D.el. 15. Leaf with distal right portion obscured by *D.el.* 16.
D.el. 16. An almost complete leaf with left branch obscured by D.el. 15.

QMF52275H and QMF52275J Upper surface
D.el. 14. Base only present.
D.el. 15. Almost complete leaf.
D.el. 16. Almost complete leaf.
The above three leaves form a single fascicle aligned with the main axis.
The petiole of *D.el.* 14 is attached to the main axis. The basal portions of *D.el.* 15 and *D.el.* 16 are obscured in the matrix.
D.el. 17. A small leaf fragment aligned with main axis.

QMF52275H Upper surface and QMF52275J Lower surface (not illustrated)
D.od. 5 and 6. Fragments of leaves.

QMF52275G Upper surface.
S4 and S5. Thin stems departing from main axis.

QMF52275G Lower surface.
D.el. 18. Almost complete leaf possibly aligned with S. 6.
D.od. 7. Small leaf fragment.
D.od. 8. Portion of leaf.
S.6. Stem.

QMF52275F Upper surface.
S.6. Stem aligned with, and possibly originating from main axis.
D.od. Small leaf fragment.

QMF52275F Lower surface. (not illustrated)
An uneven siltstone bedding plane with numerous *D.od.* leaves.

Key
Ma = Main axis.
D.el. = *Dicroidium elongatum*
D.od. = *Dicroidium odontopteroides*
S = Stem

FIG. 12. Serial depictions of the upper and lower surfaces of blocks to show position and alignment of the leaves and stem branches associated with semi-vertical axis. Based on blocks QMF52275F–K.

correct position to also have been attached to the stem The spacing between fascicles or leafless protuberances ranges from 15mm to c. 20mm apart. The R3 reconstruction (for definitions see Anderson & Anderson, 2003, p.44) of this horizontal stem (Fig. 4) depicts only the leaves actually preserved on the fossil together with its leafless short shoots. When compared with the abundance of leaves attached to the semi-vertical stem (Figs 10–12) this stem in life would have had much denser foliage. Another block QMF52275R and S (Fig. 13) of uncertain relationship to the above stems shows portions of three or possibly four adjacent fascicles each composed of three leaves to 90mm long. The irregular arrangement of the fascicles and protuberances along the

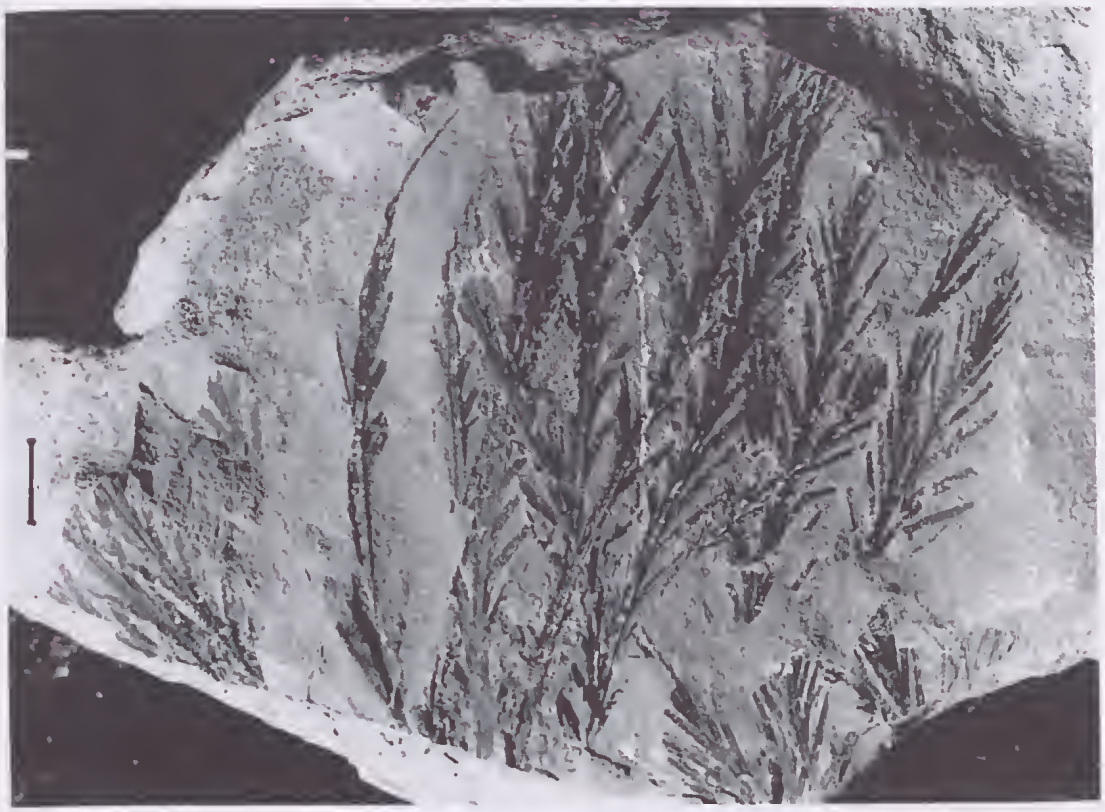


FIG. 13. Portions of four associated Dicroidium elongatum leaf fascicles. QMF52275R. Scale = 10mm.

compressed stem suggests a spiral arrangement in life and the probability that they were short shoots. The Antarctic stem described by Axsmith et al. (2000) as bearing a *Dicroidium* leaf on a long shoot also bears well-developed widely-spaced leafless short shoots that show evidence of leaf scars, a feature not well-preserved on the protuberances on the stems of the Dinmore material which are carbonaceous compressions.

DISCUSSION

This important new find of stems with attached *Dicroidium elongatum* leaves provides an insight into the habit of this particular *Dicroidium* plant. The attached and adjacent groups of leaves described here as fascicles probably represent closely-spaced spirals of leaves on short shoots similar to those seen in extant *Ginkgo biloba* first to second year short shoots. The short shoots themselves are also closely arranged spirals along the stems. The extreme variability in size of the leaves in a single fascicle (Figs 5–7) is also closely similar to that of *G. biloba*.

The stem preserved in a semi-vertical position (Fig. 8A, B) suggests a small woody branching shrub or young tree in its position of growth in a waterway, being bent at an angle during a period of high current activity and with its spiral of leaf fascicles becoming preserved horizontal to the bedding plane by the later gently accumulating layers of sediment. Its small shrub-like size as preserved provides no indication of possible size at maturity. The two horizontally preserved leaf-bearing stems (Figs 1–7) appear to be independent as no connection has been established with the third semi-vertically preserved stem (Figs 9, 10). They are probably detached branches from separate plants possibly of tree size.

ACKNOWLEDGEMENTS

Dr Barry McKelvey has provided information on the possible origin and nature of the fossil-bearing sediments. WBKH acknowledges support from the Betty Mayne Research Fund.

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REVISION OF THE GENUS *HABUTARUS* BALL & HILCHIE FROM THE AUSTRALIAN REGION (INSECTA, COLEOPTERA, CARABIDAE, LEBIINAE)

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As a third part of a general revision of the Oriental-Australian species formerly assigned to the genus *Anomotarus* Chaudoir (s.l.), the genus *Habutarus* Ball & Hilchie is revised. *Nototarus crassiceps* (Macleay) and *N. morosus* Sloane from Australia, and *N. pilosus* Baehr from New Guinea are herein transferred from the genus *Nototarus* Chaudoir of the subtribe Calleidina to the genus *Habutarus* Ball & Hilchie of the subtribe Apenina. A new subgenus, *Setitarus* subgen. nov. is erected for *N. pilosus* Baehr. For nomenclatural stability, a lectotype is designated for *Nototarus crassiceps* (Macleay). The following new species of *Habutarus* are described: *H. abboti, H. calderi, H. canaliculatus, H. chillagoensis, H. convexipennis, H. demarzi, H. eungellae, H. iridipennis, H. kirramae, H. laticeps, H. monteithi, H. nitidicollis, H. opacipennis, H. parviceps, H. punctatipennis, H. rugosipennis* and *H. weiri* from Australia, and *H. madang* and *H. wau* from New Guinea. Due to its close relationships to the African-Oriental genus *Cymindoidea* Castelnau, the genus *Habutarus* represents an Oriental faunal element that immigrated into the Australian Region only after the Australian plate came in contact with the South Asian insular arc some 10 mya. The genus subsequently underwent a period of rapid speciation, mainly in the montane rainforests along the east coast of Queensland. Some species, however, also occur in more open forests in northern Queensland and the Top End of the Northern Territory. Most species are very closely related which suggests very recent, probably Pleistocene speciation events. ❐ *Coleoptera, Carabidae, Lebiinae, Habutarus sp. nov., Setitarus subgen. nov., Australia, New Guinea.*

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The lebiine subgenus *Habutarus* was proposed by Ball & Hilchie (1983) for the unique New Guinean species *Nototarus papua* Darlington. Based on the structure of the male and female genitalia and of the mouthparts, the authors recognised that this species could not remain in the genus *Nototarus* Chaudoir of the lebiine subtribe Calleidina, but belonged to the subtribe Apenina, closely related to the Oriental-African genus *Cymindoidea* Castelnau. They included *Habutarus* as a subgenus within *Cymindoidea* but it was later raised to generic status by Lorenz (1998). Baehr (1996) described the New Guinean species *Nototarus pilosus* Baehr but was doubtful of its generic placement as it significantly deviated in structure from other congeners. This species is herewith transferred to *Habutarus*, but because of its specialised structure, is given its own subgenus *Setitarus*, subgen. nov.

Apart from both New Guinean species mentioned above, *Nototarus* Chaudoir, as presently used, is an exclusively Australian genus that Ball & Hilchie (1983), Moore et al. (1987), and Lorenz (1998, 2005) included as subgenus of *Anomotarus* Chaudoir. This seems justified in view of the close relationships of both taxa and the fact that some characters formerly used to separate the two genera are variable and hence, it is only the presence or absence of the mental tooth that differentiates the two (see Baehr, 2005b; 2006).

The apenine genus *Cymindoidea* s. str. ranges through large parts of the Ethiopian and Oriental Regions including the Greater Sunda Islands, while *Habutarus* was previously known only to occur in New Guinea (Ball & Hilchie, 1983). During examination of the Australian *Nototarus* it became evident that two species, *N. crassiceps* (Macleay) and *N. morosus* Sloane belonged to *Habitarsus*, to which they are transferred in the present paper. In addition many undescribed Australian species were discovered and they are described below. *Habutarus* is certainly closely related to *Cymindoidea*, but for biogeographical reasons I prefer to give *Habutarus* the status of a separate genus, consistent with the arrangement of Lorenz (1998, 2005).

The present paper is the third part of a general revision of the anomotarine complex in the Oriental and Australian regions that began with revisions of the subgenus *Anomotarus* s. str. (Baehr, 2004; 2005b; 2006) and will be finished by the revision of the subgenus *Nototarus* (in preparation).

MATERIAL AND METHODS

A total of 81 specimens were examined, mainly from collections by G. B. Monteith and his co-workers (Queensland Museum, Brisbane), from eastern Queensland. Additional material and types were borrowed from the following institutions and collectors: Australian Museum, Sydney (AMS), Australian National Insect Collection, Canberra (ANIC), Hungarian National Museum of Natural History, Budapest (HNMB), Institut Royal des Sciences naturelles, Brussels (IRSNB), Museum of Comparative Zoology, Cambridge/ Mass. (MCZ), Museum d'histoire naturelle, Geneva (MHNG), Museo regionale di Storia naturale, Turin (MSNT), Queensland Museum, Brisbane (QM), South Australian Museum, Adelaide (SAMA), Western Australian Museum, Perth (WAM), Luea Toledano, Verona (CBM), and from the collections made by the author and preserved in the working collection of M. Baehr, Munich (CBM).

Types of all described species were examined. For nomenclatural stability lectotypes were designated when necessary.

Standard taxonomic methods were used. Male and female genitalia were removed from specimens soaked for a night in a jar under moist atmosphere, then cleaned for a short while in hot KOH. Habitus photographs were taken with a digital camera using ProgRes Capture Basic and AutoMontage and enhanced with Corel Photo Paint 11.

Data of all examined specimens are given in full and taken verbatim from the labels, including all ciphers, notes of determiners and curators, and printed labels. The original notation for the date of collection, especially of the month (arabic, roman, abbreviations), has also been used. A '/' with a space before and after, denotes a new label, and two spaces mark a new line on the same label. Earlier determinations are recorded with quotation of the determiner. The following abbrieviations have been used: NP, National Park; NT, Northern Territory; PNG, Papua New Guinea; QLD, Queensland.

Distribution maps are based only on label data of examined specimens. In view of the limited material available for several species, the maps may not show the complete species distribution.

Measurements were taken using a stereo microscope with an ocular micrometer. Body length was measured from the apex of labrum to the apex of the elytra and therefore measurements may differ from those recorded by other authors. Length of the orbit was taken from the posterior margin of the eye to the position where the orbital curvature meets the neck. The length of the pronotum was measured along the midline, and the width of its base at the position of the posterior lateral setae. At least 6 specimens of each taxon were measured when available, otherwise all specimens were measured. Specimens of both sexes and of different size and shape were chosen. In obviously variable species or in species with a wide distribution, more specimens were measured to encompass the complete range of size and shape.

For examination of the taxonomically important surface punctation and microretículation a stereo microscope with at least 40× magnification, and a good lamp of high intensity that could be focussed was used. To study the exact definition of the microsculpture a full spectrum light is preferable. Use of uncorrected fibre-optic lights can substantially change the impression of surface structures.

BIOLOGY

Little is recorded about the habits and way of life of *Habutarus* species. This is not suprising in view of the small number of specimens available for many species. Even for the more recently sampled Australian species, which may be locally common, records are very poor, because most specimens were collected by pitfall trapping or sifting.

Species of *Habutarus* are probably ground-living and are not capable of flight. They seem to prefer rainforest or at least closed forests, although certain northern species have also been sampled in more open forest and wet tropical savannah woodland. Nevertheless, they apparently prefer a rather wet climate and more or less dense vegetation. They may live in the ground litter and hide under logs and rocks or piles of leaves. Nothing else is known about their ecological preferences.

Diet, foraging strategies, sexual behaviour, and reproductive cycles, including larvae, of *Habutarus* are completly unknown. Since their mouth parts are not specialised in any way, these beetles are probably generalists, eating any small insects, spiders, worms and other invertebrates that they are able to subdue.

Apart from the pilose and rather convex New Guinean *H. pilosus*, all species of *Habutarus* are morphologically rather uniform, apart from a certain degree of variability in body size and shape. Most species are uniformly black or dark piceous, but a few bear a more striking colour and/or pattern.

SYSTEMATICS

Habutarus Ball & Hilchie, 1983

Habutarus Ball & Hilchie, 1983: 127 (as subgenus of *Cymindoidea* Castelnau); Lorenz, 1998: 439; 2005: 465 (as genus).

TYPE SPECIES. *Nototarus papua* Darlington, 1968, by monotypy.

DIAGNOSIS. Characters of subtribe Apenina, see Ball & Hilchie (1983) and Lorenz (1998, 2005); genus characterised by medium size; depressed body; wide head bearing rather large eyes; presence of a number of coarsely punctate longitudinal furrows on frons inside of eyes; elongate, bisetose ligula; a well developed, triangular mental tooth; cordiform pronotum bearing dentiform, projecting basal angles; wide elytra bearing well impressed striae; short metathorax due to reduction of flight wings; tarsi pilose on upper surface; denticulate tarsal claws bearing 4 denticles of moderate size; male anterior tarsus little widened with biseriately squamose 1st -3rd tarsomeres; bisetose male and quadrisetose female terminal abdominal sternum; elongate male aedeagus bearing an elongate, basaly twisted, about question mark-shaped sclerite and a long filum almost twice as long as aedeagus measured from the sclerite and standing out of ostium; apenine-shaped female stylomeres Ball & Hilchie (1983) with stylomere 1 asetose at apex but bearing a spinose projection at median side, and stylomere 2 bearing a large dorso-median and a single large ventro-lateral ensiform seta, but no apical nematiform seta; lateral basal part of stylomere 2 characteristically angulate.

Species of *Habutarus* differ mainly in size and in the microstructure of the upper body surface.This varies from very rugose to largely glabrous on the head and pronotum, and glossy to obviously microreticulate on the elytra. The basic structure of the male aedeagus and, in particular, the female stylomeres are very similar in all species.

On the basis of the shape of aedeagus, and to a certain degree also body size, two species-groups can be differentiated within *Habutarus* s. str., the *crassiceps*-group that includes large species with the aedeagus more thickly sclerotised and bearing a well developed apical hook, and the *papua*-group that is composed of mostly smaller species having a more delicate, less sclerotised aedeagus with a straight apex.

Those characters that are similar in all species (metepisternum, flight wings, structure of the tarsi, terminal abdominal sternite, structure of the internal sac in the male and of the stylomeres in the female) are not repeated in the descriptions.

DISTRIBUTION. The 23 recorded species are distributed through eastern New Guinea and northern and north-eastern Australia, but the *crassiceps*-group is known only from eastern Australia, and the subgenus *Setitarus* only from Papua New Guinea.

KEY TO SPECIES OF *HABUTARUS*

1. Whole surface covered by sparse, erect pilosity, very glossy, without any trace of microreticulation; eyes smaller than usual, but markedly protruding laterally; aedeagus markedly curved, with thickened apex, genital ring laterally convex (Fig. 7D). Central PNG (subgenus *Setitarus* nov.) ..... *pilosus* (Baehr)

   Surface impilose, less glossy, usually with traces of microreticulation; eyes large, but laterally not much protruding; aedeagus less curved, genital ring narrower, laterally less convex (see Figs 2, 5, 7) (subgenus *Habutarus* s. str.) 2

2. Legs completely dark and pronotum with very coarse and dense punctation and head with extremely coarse and dense striation and body length 7.0-8.5mm; aedeagus with club-shaped hook at apex (Fig. 5F). South-eastern QLD ..... *crassiceps* (Macleay)

   Legs not completely dark, usually completely yellow or light red; when femora darkened, then pronotum with sparse and less coarse punctation and head with far less coarse and dense striation and body length < 5.5mm and aedeagus not hooked at apex and distribution different: northern NT 3

3. Intervals of elytra distinctly tectiform, with dense and distinct microreticulation, but without perceptible punctation, surface dull; body length 5-6mm 4

   Intervals of elytra not distinctly tectiform, usually with less dense and distinct microreticulation, with perceptible punctation or not, but surface almost always less dull; body length varied 6

4. Apical angles of pronotum moderately protruded; elytral striae barely punctate; apex of aedeagus with slightly less incised lower surface (Fig. 2E). Southern rim of Arnhem Land ..... *demarzi* sp. nov.

Apical angles of pronotum markedly protruded; elytral striae conspicuously punctate; apex of aedeagus with slightly more incised lower surface (Figs 2D, F). 5

5. Pronotum anteriorly wider, more cordiform, ratio w/l > 1.27, lateral margin wider, more explanate; elytra with distinct yellow margin; apex of aedeagus slightly shorter, less incised on lower surface (Fig. 2F). Kakadu NP . . . . . *canaliculatus* sp. nov.

Pronotum anteriorly narrower, less cordiform, ratio w/l < 1.24 , lateral margin narrow, not explanate; elytra without distinct yellow margin; apex of aedeagus slightly longer, more incised on lower surface (Fig. 2D). Northern and north-western NT. . . . . *morosus* (Sloane)

6. Femora perceptibly darker than tibiae and centre of head barely punctate and centre of pronotum impunctate or punctate but punctation sparse and regular. Northern NT 7

Femora yellow or light red, not darker than tibiae; punctation of head and pronotum variable. Distribution different: either eastern QLD or PNG 8

7. Elytra with coarse, irregular punctation, punctures in some areas forming transverse or oblique furrows, surface rather dull; pronotum wider and shorter, less cordiform, ratio w/l 1.32; aedeagus unknown. Southern rim of Arnhem Land. . . . . *rugosipennis* sp. nov.

Elytra barely punctate, surface glossy and highly sericeous; pronotum narrower and longer, more cordiform, ratio w/l 1.29; aedeagus unknown. Kakadu NP . . . . . *convexipennis* sp. nov.

8. Head and pronotum with dense and very rugose, in some areas furrow-like, punctation and elytra with distinct microreticulation and rather dull surface. Mountains and tablelands south of Townsville 9

At least pronotum with less dense and far less rugose punctation that is furrow-like only on head; elytra rarely with fairly distinct microreticulation but always with rather glossy surface. Mountains and tablelands north of Townsville, and PNG 12

9. Colour of elytra red and somewhat variegated; each elytron quadripunctate; aedeagus unknown. Eungella Plateau and environs, west of Mackay. . . . . *eungellae* sp. nov.

Colour of elytra unicolourous black; each elytron bipunctate 10

10. Body size < 6.5mm; elytra very dull; apex of aedeagus not definitely hooked, only thickened (Fig. 7A). Mt Abbot west of Bowen . . . . . *abboti* sp. nov.

Body size > 8mm; elytra less dull; apex of aedeagus definitely hooked (Figs 5G-H). 11

11. Head and pronotum wider, ratio w/l of pronotum 1.27; eyes smaller in comparison to orbits, ratio eye/orbit c. 1.4; elytra shorter and wider, more oviform, ratio l/w 1.43; punctation of intervals distinct; apex of aedeagus slightly longer (Fig. 5G). Kroombit Tops, south-west of Calliope . . . . . *laticeps* sp. nov.

Head and pronotum narrower, ratio w/l of pronotum 1.24; eyes larger in comparison to orbits, ratio eye/orbit c. 2.5; elytra longer and narrower, less oviform, ratio l/w 1.50; punctation of intervals barely visible; apex of aedeagus slightly shorter (Fig. 5H). Carmila, south of Mackay. . . . . *parviceps* sp. nov.

12. Centre of head not striate, only finely and sparsely punctate 13

Centre of head perceptibly striate and coarsely punctate 15

13. Body size < 5.5mm; disc of pronotum finely punctate; elytra glossy black with more or less distinct yellow border; apex of aedeagus elongate, but not hooked (Fig. 2H). Northern Cape York Peninsula . . . *monteithi* sp. nov.

Body size > 7mm; disc of pronotum almost impunctate; elytra shining piceous; apex of aedeagus either short (Fig. 5E), or hooked (Fig. 7B). Distribution different 14

14. Pronotum wider, ratio w/l >1.23; setiferous punctures on 3rd interval impressed, wider and deeper than usual; aedeagus with distinct apical hook (Fig. 7B). Carbine Tableland . . . . . *nitidicollis* sp. nov.

Pronotum narrower, ratio w/l <1.20; setiferous punctures on 3rd interval normal, not deeply impressed; aedeagus with simple apex (Fig. 5E). Kirrama Range, south-west of Tully. . . . . *kirramae* sp. nov.

15. Disc of pronotum perceptibly microreticulate; either elytra short and wide, oviform, and species from PNG, or elytra light brown with lighter humeri, remarkably sericeous, and with large setiferous punctures. 16

Disc of pronotum not microreticulate; elytra always rather elongate and less oviform, black or bronzed, but not sericeous. Northern QLD. 19

16. Elytra not oviform, red-brown with lighter humeri, remarkably sericeous, and with large setiferous punctures, intervals depressed; centre of pronotum punctate; aedeagus with hook-shaped apex (Fig. 7C). Mt Finnigan and mountains west of Cape Tribulation, northern QLD . . . . . *iridipennis* sp. nov.

Elytra oviform, colour varied but never obviously sericeous, setiferous punctures small, intervals convex; centre of pronotum barely punctate; aedeagus with unarmed apex. PNG . . . . . 17.

17. Elytra bicolourous, disc piceous, humeri and lateral margins perceptibly lighter; apex of aedeagus short and stout (Fig. 2A). Dobodura, Oro Prov., Papua Peninsula . . . . . *papua* (Darlington)

Elytra unicolourous black; apex of aedeagus longer and less stout (Figs 2B-C). Distribution different 18

18. Body size > 5mm; elytra shorter and wider, ratio l/w < 1.39, dorsally less convex; punctation of intervals rather distinct; aedeagus thicker, apex longer (Fig. 2B). Vicinity of Wau, Morobe Prov. . . . . *wau* sp. nov.

Body size < 4.5mm; elytra longer and narrower, ratio l/w 1.44, dorsally more convex; punctation of intervals indistinct; aedeagus slender, apex shorter (Fig. 2C). Vicinity of Madang, Madang Prov. . . *madang* sp. nov.

19. Microreticulation of elytra distinct, surface rather dull; aedeagus slender, with straight apex (Fig. 2G). Hann Tableland, northwest of Cairns . . *opacipennis* sp. nov.

Microreticulation of elytra absent, surface very glossy; apex of aedeagus either hooked, or variously bent, rarely straight 20

20. Elytra piceous; punctation of elytral intervals indistinct, barely visible; pronotum with narrower base, with less produced apical angles, ratio widest diameter/base > 1.35; apex of aedeagus at tip slightly bent down, left paramere bi-impressed near apex (Fig. 5D). Mountains near Cooktown . . . . . *calderi* sp. nov.

Elytra black; punctation of elytral intervals distinct; pronotum with wider base, with markedly produced apical angles, ratio widest diameter/base < 1.33; aedeagus different. Distribution different 21

21. Punctation of intervals very distinct, easily recognised, surface of elytra less iridescent; apical angles of pronotum

rather acute; apex of aedeagus impressed (Figs 5A-B) 22

Punctation of intervals less distinct, more difficult to recognise, surface of elytra remarkably irideseent; apical angles of pronotum rounded; apex of aedeagus not impressed (Fig. 5C). McIlwraith Range, lower Cape York Peninsula ..... *weiri* sp. nov.

22. Body size slightly larger (length > 6mm); pronotum anteriorly more curved inwards, with narrower base, ratio widest diameter/base > 1.32; apex of aedeagus shorter and thicker (Fig. 5A). Cairns and vicinity ..... *punctatipennis* sp. nov.

Body size slightly smaller (length 5.65mm); pronotum anteriorly less curved inwards, with wider base, ratio widest diameter/base 1.29; apex of aedeagus longer and very slender (Fig. 5B). Vicinity of Chillagoe, inland northern QLD. ..... *chillagoensis* sp. nov.

PAPUA-GROUP

Generally small species, bearing a moderately sclerotised aedeagus with the apex straight, never hook-shaped.

Habutarus papua (Darlington, 1968) (FIGS 1A, 2A, 8, 9)

Nototarus papua Darlington, 1968: 186.

Habutarus papua (Darlington). Ball & Hilchie, 1983: 127, Fig. 40; Lorenz, 1998: 439; 2005: 465.

MATERIAL. HOLOTYPE: ♂, Dobodura Papua N.G. Mar-July, 1944 Darlington / Holotype *Nototarus papua* Darl. / MCZ Holotype 31491 (MCZ). PARATYPES: 2♂♂, 3♀♀, same data / one ♂ labelled: *Cymindoidea (Habutarus) papua* Darl. Det. George E. Ball 1990 (CBM, MCZ).

DIAGNOSIS. Distinguished from other New Guinean species by colouration and the very indistinct punctation of elytra.

REDESCRIPTION. For comparison with the new species some characters are redescribed.

Measurements. (Table 1) Length:4.9-5.2mm; width: 1.95-2.1mm. Ratios. Length eye/orbit: 2.2-2.4; width/length of pronotum: 1.28-1.31; width widest diameter/base of pronotum: 1.43-1.44; width pronotum/head: 1.22-1.24; length/width of elytra: 1.37-1.41; width elytra/pronotum: 1.43-1.45.

Colour. (Fig. 8) Head and pronotum black, labrum red. Anterior part of lateral margins of pronotum narrowly and more or less distinctly red. Elytra piceous, though humeral area and epipleura red, elytra distinctly lighter than fore body, very glossy. Palpi and antennae light red. Legs yellow.

Head. Large, with fairly large, moderately protruding eyes with length slightly more than twice that of orbits. Mentum with acute median tooth. Apical palpomere of ♀ labial palpus about half as wide as long, in ♂ markedly securiform. Antenna short, just attaining base of pronotum. Head dorsal surface with coarse and dense longitudinal strioles shortened anteriorly and posteriorly and in middle of frons less distinct, and with scattered punctures. Microreticulation distinct, isodiametric, visible medially but not laterally. Surface rather glossy.

Pronotum. Wide and cordiform, surface depressed. Apex shallowly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex mostly margined apart from a narrow space in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Disc sparsely and finely punctate, without distinct transverse strioles, punctation laterally denser and slightly coarser. Microreticulation isodiametric, distinct, though somewhat superficial, surface moderately dull.

Elytra. Comparatively short and wide, relatively convex, clearly widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel very narrow. Striae impressed, complete, moderately deep, finely crenulate. Intervals very slightly convex, each with an irregular and sparse row of very fine punctures that are difficult to detect, and with superficial, transverse microreticulation, surface glossy. 3rd interval bipunctate, punctures coarse, the anterior one situated in centre of interval, slightly in front of middle, the posterior one near 3rd stria at apical third, but location irregular.

Ventral surface. Prosternum and proepisternum rather coarsely, but superficially punctate-striolate and with distinct microreticulation, prosternum also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate but microreticulate.

Male genitalia. (Fig. 2A) Rather large in comparison to body size. Genital ring narrow, very slightly asymmetric. Base rather deep. Aedeagus compact, slightly asymmetric, orifice short, situated on left side. Lower surface very slightly concave, apex short and stout, straight, obtuse at tip. Parameres very dissimilar, asetose, left one large, wide, triangular, right one small, moderately elongate.

Female genitalia. (Fig. 8) See genus diagnosis.

Variation. No significant variation noted.

COLLECTING CIRCUMSTANCES. According to Darlington (1968: 186) the type series was collected 'in flood debris from the floor of rain forest'.

DISTRIBUTION. (Fig. 9) Eastern Papua New Guinea, known only from type locality.

RELATIONSHIPS. Related to other New Guinean species, though these other species are likely more closely related to each other than to *H. papua*.

Habutarus wau sp. nov.
(Figs 1B, 2B, 9)

ETYMOLOGY. The name refers to the type locality, the vicinity of Wau.

MATERIAL. HOLOTYPE: ♂, PAPUA NG: Morobe, Mt Kaindi, 1700m, 25.V.1992, G. Cuecodoro #8A (MHNG). PARATYPES: 1♂, PAPUA NG: Morobe, Mt Mission, Bitoi Rd, 1350m, 22.V.1992, G. Cuecodoro #68 (CBM); 1♀, NEW GUINEA/N/ Wau, 8.IX.1968.// No.NG-W.R.19/leg. Dr. I. Lokes (HNMB).

DIAGNOSIS. Distinguished from other New Guinean species either by its larger size and distinctly shorter and wider elytra (from *H. madang* sp. nov.) or by its uniformly black colour and distinct elytral punctation (from *H. papua* (Darlington)).

DESCRIPTION. *Measurements* (Table 1). Length: 5.5-5.6mm; width: 2.1-2.2mm. Ratios. Length eye/orbit: 1.7-1.9; width/length of pronotum: 1.23-1.26; width widest diameter/base of pronotum: 1.34-1.40; width pronotum/head: 1.17-1.21; length/width of elytra: 1.34-1.39; width elytra/pronotum: 1.46-1.51.

Colour. (Fig. 1B) Body uniformly black. Palpi, antennae and legs light red.

Head. Large, with fairly large, moderately protruding eyes that are almost twice length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex less than half as wide as long, in ♂ securiform but apex less wide than in most other species. Antenna short, just attaining base of pronotum. Dorsal surface near eyes with coarse and dense longitudinal strioles that end in front of posterior margin of eyes. Centre of frons and vertex with sparse, moderately coarse punctures but without any strioles. Superficial isodiametric microreticulation visible in middle but not laterally. Surface glossy.

Pronotum. Wide and cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined except near apical angles, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Most of disc sparsely and finely punctate, almost glossy, without distinct transverse strioles. Only at apex, base, and near lateral margin punctation coarser and denser. Superficial traces of microreticulation visible at high magnification, surface very glossy.

Elytra. Comparatively wide, moderately depressed, clearly widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, finely crenulate. Intervals very slightly convex, median ones almost depressed, each with a well visible, irregular row of fairly coarse punctures and with superficial, isodiametric microreticulation that is visible only at high magnification, surface fairly glossy. 3rd interval bipunctate, punctures coarse, situated in middle of interval, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum and proepisternum very sparsely punctate, latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate.

Male genitalia. (Fig. 2B) Rather large in comparison to body size. Genital ring narrow, barely asymmetric. Base rather deep. Aedeagus compact, slightly asymmetric, orifice short, situated on left side. Lower surface very slightly concave, apex fairly elongate, straight, fairly acute at tip. Parameres very dissimilar, asetose, left one large, wide, triangular, right one small, moderately elongate.

Variation. Very little variation noted.

COLLECTING CIRCUMSTANCES. Largely unknown. So far collected at medium altitudes between about 1300 and 1700m.

DISTRIBUTION (FIG. 9). Vicinity of Wau, eastern central Papua New Guinea.

RELATIONSHIPS. Probably more closely related to *H. madang* sp. nov. than to *H. papua*.

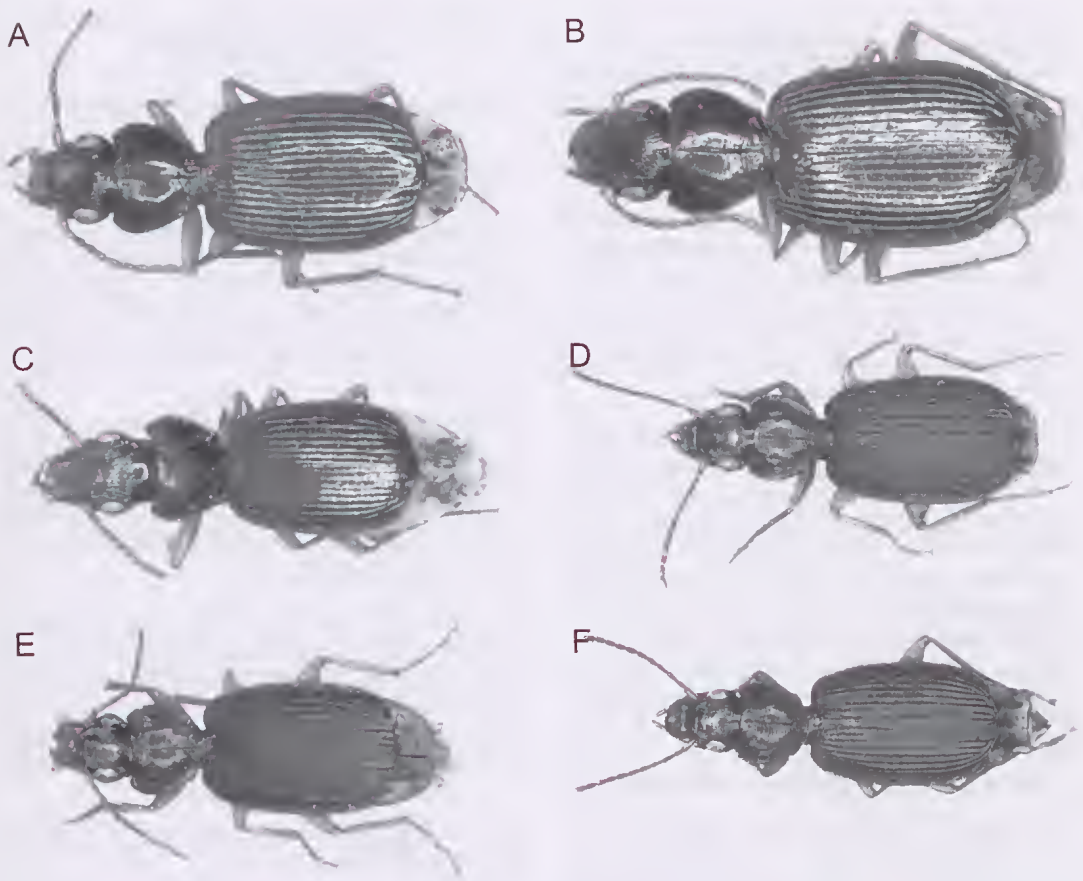

FIG. 1. Dorsal views of *Habutarus* spp. (body length in brackets). A, *H. papua* (Darlington) (4.9mm); B, *H. wau* sp. nov. (5.5mm); C, *H. madang* sp. nov. (4.4mm); D, *H. morosus* (Sloane) (5.0mm); E, *H. demarzi* sp. nov. (6.0mm); F, *H. canaliculatus* sp. nov. (6.0mm).

Habutarus madang sp. nov.
(Figs 1C, 2C, 9)

ETYMOLOGY. The name refers to the province of the type locality.

MATERIAL. HOLOTYPE: ♂, Coll. I.R.Sc.N.B. Papua New Guinea, Kalagima river, Madang prov., coconut + cacao plant, wet leaf litter, I.G: 26373, 21.V.1981, Leg. J. Van Goethem (IRSNB).

DIAGNOSIS. Distinguished from the other two New Guinean species of the *papua*-group by its smaller size and longer and narrower elytra.

DESCRIPTION. *Measurements.* (Table 1). Length: 4.4mm; width: 1.7mm. Ratios. Length eye/orbit: 2.2; width/length of pronotum: 1.29; width widest diameter/base of pronotum: 1.43; width pronotum/head: 1.21; length/width of elytra: 1.44; width elytra/pronotum: 1.44.

Colour. (Fig. 1C) Whole dorsal surface almost black. Palpi, antennae, and legs light red.

Head. Large, with fairly large, moderately protruding eyes that are slightly more than twice length of orbits. Mentum with acute median tooth. Labial palpus in ♂ securiform but apex less wide than in most other species. Antenna short, barely attaining base of pronotum. Upper surface near eyes with coarse and dense longitudinal strioles that end in front of posterior margin of eyes. Centre of frons and vertex with sparse, moderately coarse punctures but without any strioles. Superficial, isodiametric microreticulation visible. Surface fairly glossy.

Pronotum. Wide and cordiform, surface moderately convex. Apex slightly excised, base in middle produced. Apical angles projecting

though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined except for the lateral parts close to apical angles, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin very narrow throughout. Most of disc very sparsely and finely punctate, almost glossy, with superficial transverse strioles only laterally. At apex, base and near lateral margin punctation slightly coarser and denser. Isodiametric microreticulation comparatively distinct, surface moderately glossy.

Elytra. Comparatively narrow and elongate, fairly depressed, very slightly widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, finely crenulate. Intervals very slightly convex, each with an irregular row of fine punctures and with superficial, though fairly distinct, isodimateric to slightly transverse microreticulation, surface moderately glossy. 3rd interval bipunctate, punctures coarse, situated in middle of interval, the anterior one slightly in front of middle, the posterior one at apical third.

Ventral surface. Prosternum and proepisternum sparsely but coarsely punctate and striolate, with distinct microreticulation, rather dull, the latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate, glossier.

Male genitalia. (Fig. 2C) Rather large in comparison to body size. Genital ring narrow, very slightly asymmetric. Base rather deep. Aedeagus comparatively narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface slightly concave, apex fairly elongate, straight, fairly acute at tip. Parameres very dissimilar, asetose, left one large, short and wide, triangular, right one small, rather short.

Variation. Unknown.

COLLECTING CIRCUMSTANCES. The single specimen was collected in 'coconut + cacao plant, wet leaf litter', which is in a secondary habitat. Nothing is known about the altitudal range occupied by this species.

DISTRIBUTION. (Fig. 9) Madang Province, northern Papua New Guinea. Known only from the type locality.

RELATIONSHIPS. Probably more closely related to *H. wau* sp. nov. than to *H. papua*.

Habutarus morosus (Sloane, 1915), comb. nov.
(Figs 1D, 2D, 10)

Nototarus morosus Sloane, 1915: 470; Csiki 1932: 1492; Moore et al. 1987: 308; Lorenz 1998: 471; 2005: 497.

MATERIAL. HOLOTYPE: ♂, Pt. Darwin Dodd '08 / *Nototarus morosus* Sl. Type / HOLOTYPE *Nototarus morosus* Sl. PJD (ANIC). NEW MATERIAL: (1 specimen): NORTHERN TERRITORY, 1♀, 16.00S 130.28E NT GPS 13.5km NNE Bullita, Gregory Nat. Pk, 20 May 2001 T. Weir, P. Bouchard / surfaces at night (ANIC).

DIAGNOSIS. Immediately distinguished from all other species except *H. canaliculatus* sp. nov. and *H. demarzi* sp. nov. by its carinate elytral striae. From both latter species it is distinguished by a narrower pronotum and the uniformly dark lateral margins of the elytra.

DESCRIPTION. *Measurements.* (Table 1) Length: 5.0mm; width: 1.95-2.0mm. Ratios. Length eye/orbit: 3.1-3.2; width/length of pronotum: 1.23-1.24; width widest diameter/base of pronotum: 1.28-1.33; width pronotum/head: 1.23-1.25; length/width of elytra: 1.51-1.52; width elytra/pronotum: 1.47-1.48.

Colour. (Fig. 1D) Body uniformly black. Palpi, antennae, and legs light red.

Head. Large, with large, moderately protruding eyes that are about 3 times length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ unknown. Antenna medium sized, surpassing base of pronotum by about one antennomere. Upper surface near eyes with coarse and dense longitudinal strioles that end in front of posterior margin of eyes. Centre of frons and vertex with fairly dense, moderately coarse punctures that combine to form some short, superficial strioles on vertex. Superficial isodiametric microreticulation visible in middle but not laterally. Surface moderately glossy.

Pronotum. Moderately wide, cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions

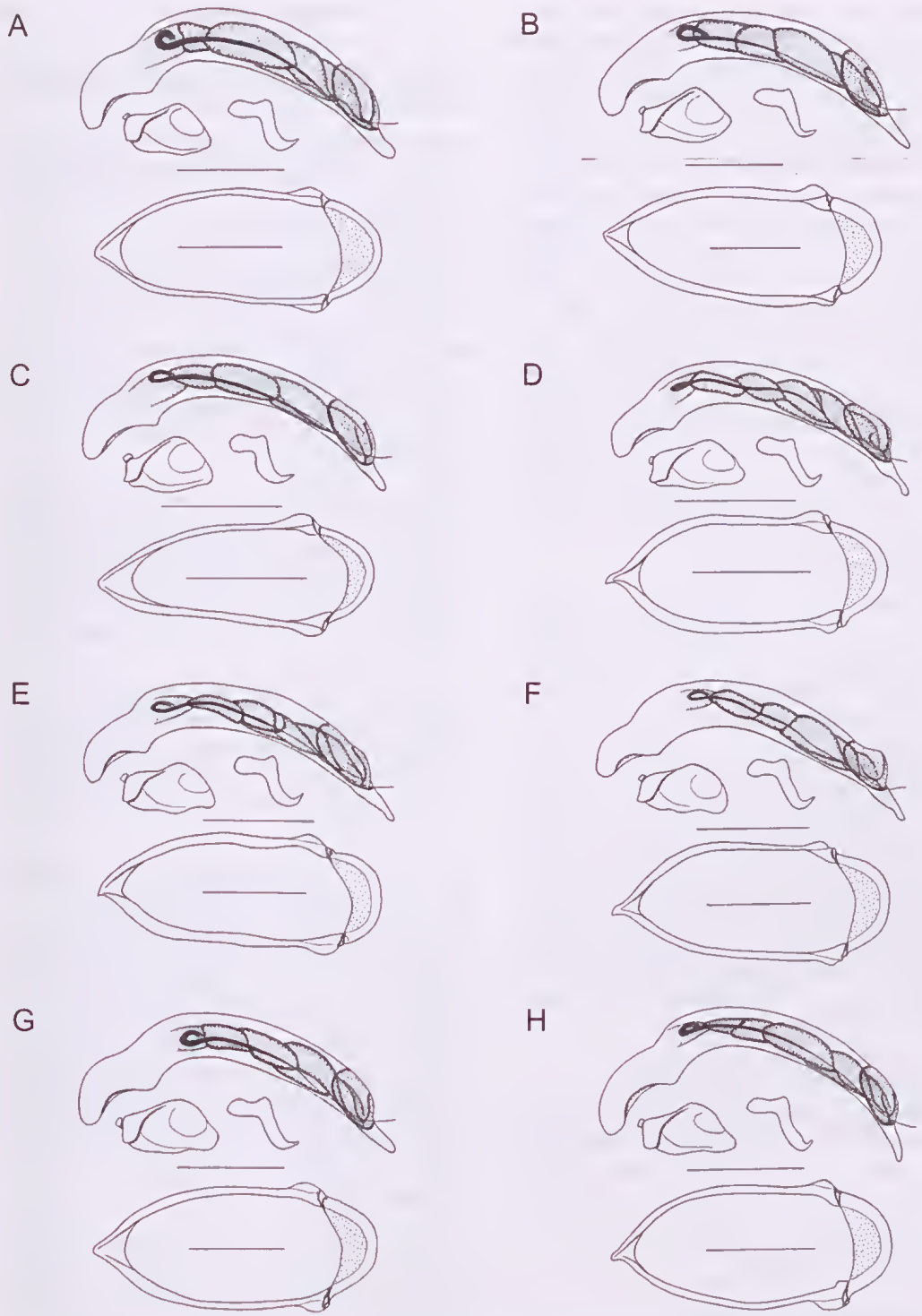

FIG. 2. Male genitalia of *Habutarus* spp. showing aedeagus (upper), parameres (centre) and genital ring (lower), scale 0.5mm. A, *H. papua* (Darlington); B, *H. wau* sp. nov.; C, *H. madang* sp. nov.; D, *H. morosus* (Sloane); E, *H. demarzi* sp. nov.; F, *H. canaliculatus* sp. nov.; G, *H. opacipennis* sp. nov.; H, *H. monteithi* sp. nov.

lacking. Lateral margin narrow throughout. Surface densely punctate and striolate, though laterally and near base punctation even coarser and denser. Superficial traces of microreticulation visible, surface moderately glossy.

Elytra. Rather narrow and elongate, depressed, widest at middle. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, finely crenulate. Intervals convex, tectiform, with very distinct, isodiametric microreticulation, each apparently with an irregular row of punctures that are extremely difficult to detect within microreticulation, surface very dull. 3rd interval bipunctate, punctures coarse, though rather difficult to detect, situated about in middle of interval, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum and proepisternum rather coarsely punctate and striolate, and with superficial microreticulation, the latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate and glossier.

Male genitalia. (Fig. 2D) Rather large in comparison to body size. Genital ring moderately narrow, only at apex slightly asymmetric. Base rather deep. Aedeagus narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface very slightly concave, apex elongate, straight, very slightly widened at tip. Parameres very dissimilar, asetose, left one large, elongate, rather triangular, right one small, moderately elongate.

Variation. Very little variation noted.

COLLECTING CIRCUMSTANCES. The non-type specimen was captured 'on surfaces at night', probably by searching the ground using a torch.

DISTRIBUTION. (Fig. 10) Far northern and north-western Northern Territory.

RELATIONSHIPS. Together with *H. demarzi* sp. nov. and *H. canaliculatus* sp. nov., this species forms a closely related group restricted to the northern part of the Northern Territory.

Habutarus demarzi sp. nov.
(Figs 1E, 2E, 10)

ETYMOLOGY. The name is a patronym in honour of the collector of the holotype.

MATERIAL. Holotype: ♂, Austral. North. T. Beswick, I.1958, leg. H. Demarz (CBM). PARATYPE: 1♀, Nitmiluk Nat. Park, Katherine Gorge, 19-26.III.1996, P. M. Giachino / *Anomotarus* sp. Det. P. M. Giachino 1998 (MSNT).

DIAGNOSIS. Immediately distinguished from all other species except *H. morosus* and *H. canaliculatus* by the carinate elytral striae. Distinguished from *H. morosus* by a wider pronotum and the yellow lateral margins of the elytra, and from *H. canaliculatus* by less strongly projecting apical angles of the pronotum and far less coarsely punctate elytral striae.

DESCRIPTION. *Measurements* (Table 1). Length: 5.8-6.0mm; width: 2.2-2.3mm. Ratios. Length eye/orbit: 2.8-3.0; width/length of pronotum: 1.26-1.28; width widest diameter/base of pronotum: 1.27-1.30; width pronotum/head: 1.25-1.27; length/width of elytra: 1.49-1.51; width elytra/pronotum: 1.49-1.50.

Colour: (Fig. 1E) Surface unicolourous black, though labrum and apical margin of clypeus red. Lateral margins of pronotum inconspicuously and lateral margin of elytra distinctly red. Epipleura of elytra red. Palpi and antennae red, legs light red.

Head. Large, with large, moderately protruding eyes that are about 3 times length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ remarkably securiform. Antenna medium-sized, surpassing base of pronotum by about one antennomere. Upper surface near eyes with coarse and dense longitudinal strioles that end in front of posterior margin of eyes. Centre of frons and vertex with fairly dense, moderately coarse punctures that combine to form some short, superficial strioles on vertex. Superficial isodiametric microreticulation visible in middle but not laterally. Surface moderately glossy.

Pronotum. Rather wide, cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles little projecting, rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median

line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface densely punctate and striolate, though laterally and near base punctation even coarser and denser. More or less distinct traces of microreticulation visible, surface moderately glossy.

Elytra. Rather narrow and elongate, depressed, widest at middle. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel rather narrow. Striae impressed, complete, moderately deep, very finely crenulate. Intervals convex, tectiform, with very distinct, isodiametric microreticulation, each apparently with an irregular row of punctures that are extremely difficult to detect within microreticulation, surface very dull. 3rd interval bipunctate, punctures coarse, though rather difficult to detect, situated about in middle of interval, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

TABLE 1. Body mesurements and ratios of *Habutarus* spp. N, number of specimens measured. Note that separate values are given for Mt Finnigan and Cape Tribulation populations of *H. iridipennis* sp. nov. as they are each represented by only a single sex.

	N	Body length (mm)	Ratio length eye/ orbit	Ratio width/ length pronotum
papua	6	4.9-5.2	2.2-2.4	1.28-1.31
wau	3	5.5-5.6	1.7-1.9	1.23-1.26
madang	1	4.4	2.2	1.29
morosus	2	5.0	3.1-3.2	1.23-1.24
demarzi	2	5.8-6.0	2.8-3.0	1.26-1.28
canaliculatus	5	5.2-6.0	2.7-3.0	1.27-1.29
rugosipennis	1	5.0	2.8	1.32
opacipennis	1	5.9	2.3	1.22
monteithi	2	5.3-5.4	2.3-2.4	1.25-1.27
punctatipennis	3	6.0-6.1	2.0-2.2	1.19-1.22
chillagoensis	1	5.65	2.05	1.22
weiri	3	5.9-6.1	2.1-2.3	1.24-1.27
calderi	6	4.8-6.0	2.0-2.2	1.20-1.23
kirramae	3	6.4-6.9	1.6-1.8	1.15-1.20
convexipennis	1	5.25	2.0	1.29
crassiceps	10	6.8-8.4	1.5-2.2	1.29-1.37
laticeps	1	8.7	1.4	1.27
parviceps	1	8.6	2.5	1.24
abboti	3	6.0-6.3	2.5-2.6	1.26-1.30
nitidicollis	6	6.6-7.7	1.8-2.0	1.23-1.28
iridipennis ♂ (C. Tribulation)	5	5.35-5.5	2.2-2.3	1.20-1.27
iridipennis ♀ (Mt Finnigan)	3	5.2-6.1	1.7-1.8	1.19-1.25
eungellae	2	7.0-7.2	1.9-2.2	1.34-1.38
pilosus	1	6.8	1.6	1.22
	Ratio widest diameter/base pronotum	Ratio diameter/ base pronotum/ head	Ratio length/ width elytra	Ratio width elytra/pronotum
papua	1.43-1.44	1.22-1.24	1.37-1.41	1.43-1.45
wau	1.34-1.40	1.17-1.21	1.34-1.39	1.46-1.51
madang	1.43	1.21	1.44	1.44
morosus	1.29-1.33	1.23-1.25	1.51-1.52	1. 47-1.48
demarzi	1.27-1.30	1.25-1.27	1.49-1.51	1.49-1.50
canaliculatus	1.30-1.33	1.26-1.30	1.50-1.53	1.46-1.51
rugosipennis	1.31	1.23	1.44	1.47
opacipennis	1.32	1.23	1.47	1.44
monteithi	1.39-1.41	1.26-1.27	1.49-1.50	1.42-1.44
punctatipennis	1.32-1.33	1.21-1.25	1.50-1.51	1.45-1.49
chillagoensis	1.29	1.26	1.51	1.48
weiri	1.30-1.33	1.28-1.31	1.46-1.51	1.40-1.42
calderi	1.34-1.39	1.19-1.25	1.47-1.52	1.44-1.52
kirramae	1.33-1.36	1.21-1.25	1.48-1.50	1.45-1.52
convexipennis	1.36	1.29	1.42	1.44
crassiceps	1.36-1.44	1.26-1.32	1.37-1.45	1.35-1.44
laticeps	1.35	1.24	1.43	1.40
parviceps	1.37	1.21	1.50	1.41
abboti	1.38-1.39	1.27-1.28	1.39-1.42	1.43-1.48
nitidicollis	1.39-1.44	1.23-1.29	1.46-1.50	1.41-1.47
iridipennis ♂ (C. Tribulation)	1.38-1.44	1.19-1.22	1.43-1.46	1.41-1.46
iridipennis ♀ (Mt Finnigan)	1.39-1.41	1.21-1.26	1.38-1.40	1.46-1.51
eungellae	1.38-1.43	1.32	1.39-1.41	1.39-1.40
pilosus	1.36	1.21	1.36	1.42

Ventral surface. Prosternum and proepisternum rather coarsely punctate and striolate, and with superficial microreticulation, the latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate and glossier.

Male genitalia. (Fig. 2E) Rather large in comparison to body size. Genital ring moderately narrow, only at apex slightly asymmetric. Base moderately deep. Aedeagus comparatively narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface slightly concave, apex elongate, straight, very slightly widened at tip. Paramcres very dissimilar, asetose, left one large, elongate, rather triangular, right one small, moderately elongate.

Variation. Apart from some differenees in relative shape of pronotum, very little variation noted.

COLLECTING CIRCUMSTANCES. Unknown.

DISTRIBUTION. (Fig. 10) Southern rim of Arnhem Land, northern Northern Territory.

RELATIONSHIPS. Together with *H. morosus* and *H. canaliculatus* sp. nov. this species forms a closely related group restricted to the northern part of the Northern Territory.

Habutarus canaliculatus sp. nov.
(Figs 1F, 2F, 10)

ETYMOLOGY. The name refers to the deeply impressed elytral striae.

MATERIAL. HOLOTYPE: ♂, NT. 2.5km NE Jabiru East. East Magela Grassland. Litter Sample: 2 April 1982. M. D. Armstrong (SAMA). PARATYPES: 2♂♂, 1♀, same data (CBM, SAMA); 1♂, AUSTRALIA, N. T. Kakadu N.P. Cooinda, 25-26/12/96, Leg. L. Toledano, R. Olivieri (CBM).

DIAGNOSIS. Immediately distinguished from all other species except *H. morosus* and *H. demarzi* by the carinate elytral striae. Distinguished from *H. morosus* by a wider pronotum and the yellow lateral margins of the elytra, and from *H. demarzi* by the more strongly projecting apical angles of the pronotum and the far more coarsely punctate elytral striae.

DESCRIPTION. *Measurements*. (Table 1) Length: 5.2-6.0mm; width: 2.0-2.3mm. Ratios. Length eye/orbit: 2.7-3.0; width/length of pronotum: 1.27-1.29; width widest diameter/base of pronotum: 1.30-1.33; width pronotum/head: 1.26-1.30; length/width of elytra: 1.50-1.53; width elytra/pronotum: 1.46-1.51.

Colour: (Fig. 1F) Surface unicolourous black, or elytra and sometimes also pronotum more or less dark piceous, though labrum and apical margin of clypeus red. Lateral margins of pronotum less conspicuously and lateral margins of elytra distinctly red. Epipleura of elytra red. Palpi and antennae red, legs light red.

Head. Large, with large, moderately protruding eyes that are about 3 times length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ remarkably securiform. Antenna medium-sized, surpassing base of pronotum by about one antennomere. Upper surface near eyes with coarse and dense longitudinal strioles that end in front of posterior margin of eyes. Centre of frons and vertex with fairly dense, moderately coarse punctures that combine to form some short, superficial strioles on vertex. Superficial isodiametric microreticulation more or less distinct in middle. Surface moderately glossy.

Pronotum. Wide, cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles rather projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface densely punctate and striolate, though laterally and near base punctation even coarser and denser. More or less distinct traces of microreticulation visible, surface moderately glossy.

Elytra. Rather narrow and elongate, depressed, widest at middle. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel rather narrow. Striae impressed, complete, moderately deep, rather coarsely crenulate. Intervals convex, tectiform, with very distinct, isodiametric microreticulation, each apparently with an irregular row of punctures that are extremely difficult to detect within microreticulation, surface very dull. 3rd interval bipunctate, punctures coarse, though rather difficult to detect, situated about in middle of interval, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum and procpisternum rather coarsely punctate and striolate, and with superficial microreticulation, the latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate and glossier.

Male genitalia. (Fig. 2F) Rather large in comparison to body size. Genital ring moderately narrow, only at apex slightly asymmetric. Base rather deep. Aedeagus comparatively narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface almost straight, apex moderately elongate, straight, very slightly widened at tip. Parameres very dissimilar, asetose, left one large, elongate, rather triangular, right one small, moderately elongate.

Variation. The only substantial variation encountered was in the size of the eyes relative to the orbits, which seems to exhibit some sexual variation, with males having slightly larger eyes.

COLLECTING CIRCUMSTANCES. Most specimens were captured in 'litter' in tropical wet grassland.

DISTRIBUTION. (Fig. 10) So far known from the northern parts of Kakadu National Park at the eastern margin of Arnhem Land, in far northern Northern Territory.

RELATIONSHIPS. Together with *H. morosus* and *H. demarzi* sp. nov. this species forms a

elosely related group restrieted to the northern part of the Northern Territory.

Habutarus rugosipennis sp. nov.
(Figs 3A, 10)

ETYMOLOGY. The name refers to the highly rugose elytral intervals.

MATERIAL. HOLOTYPE: ♀, Australia, NT, Katherine Gorge, 15km NE. Katherine, 6.-8.11.1984, M. Baehr (CBM).

DIAGNOSIS. Immediately distinguished from all other species by the eombination of a glossy, barely striolate head, glossy pronotum, and the highly rugose punctation of the elytra.

DESCRIPTION. *Measurements.* (Table 1) Length: 5.0mm; width: 1.9mm. Ratios. Length eye/orbit: 2.8; width/length of pronotum: 1.32; width widest diameter/base of pronotum: 1.31; width pronotum/head: 1.23; length/width of elytra: 1.44; width elytra/pronotum: 1.47.

Colour. (Fig. 3A) Head and pronotum glossy blaek, elytra very dark pieeous. Labrum and mandibles dark red. Palpi and antennae red. Legs dirty yellow, but femora slightly infuseate.

Head. Large, with large, moderately protruding eyes that are almost 3 times length of orbits. Mentum with aeute median tooth. Labial palpus in ♀ at apex about half as wide as long, unknown in ♂. Antenna short, barely surpassing base of pronotum. Upper surfaee only near anterior margin of eyes with few eoarse longitudinal strioles that end about in middle of eyes. Frons and vertex with extremely sparse, rather fine eoarse punetures but without any strioles. Mieroretieulation apparently absent. Surfaee remarkably glossy.

Pronotum. Very wide, eordiform, with eomparatively narrow base, surfaee depressed. Apex slightly excised, base in middle produeed. Apieal angles little projeeting, rounded. Lateral margins evenly eonvex, not sinuate posteriorly but basal angles projeeting as minute dentieles. Base laterally oblique and exeised. Apex not margined in middle, base margined throughout, but in middle margin very fine. Median line deep and suleate. Basal impressions laeking. Lateral margin narrow throughout. Dise very sparsely and finely punetate, glossy, without transverse strioles. Only at apex, base and near lateral margin punetation eoarser and denser and strioles present. No traees of mieroretieulation visible, surface very glossy.

Elytra. Rather wide, moderately depressed, slightly widened towards apex. Basal angles projeeting but evenly rounded. Apieal margin oblique, slightly exeised. Lateral ehannel narrow. Striae impressed, eomplete, rather deep, barely erenulate. Intervals eonvex, eaeh with an irregular row of very eoarse punetures that are eommonly widened to irregular transverse furrows, giving the intervals a remarkably rough and eoriaceous appearanee. Very superfieial mieroretieulation visible mainly in the bottoms of the punetures, surfaee fairly glossy. 3rd interval bipunetate, punetures very eoarse, though diffieult to see within the eoarse punetation, situated near 3rd stria, the anterior one slightly in front of middle, the posterior one at apieal third, but loeation rather irregular.

Ventral surface. Prosternum and proepisternum sparsely and shallowly punetate, glossy, the latter sparsely pilose; mesothorax, metathorax, and abdomen almost impunetate.

Male genitalia. Unknown.

Variation. Unknown.

COLLECTING CIRCUMSTANCES. Colleeted on the ground near an artifieial light at night in open tropieal woodland.

DISTRIBUTION. (Fig. 10) Southern rim of Arnhem Land, northern Northern Territory. Known only from the type loeality.

RELATIONSHIPS. An isolated speeies that may be related to the *morosus*-subgroup, but male genitalia must be studied to eonfirm this.

Habutarus opaeipennis sp. nov.
(Figs 3B, 2G, 10)

ETYMOLOGY. The name refers to the rather opaque elytra due to distinct microreticulation.

MATERIAL. HOLOTYPE: ♂, AUST: QLD: NE Hann Tbld. Radar Stn. 26 Nov 1998 G. B. Monteith / QM BERLESATE 982, 16°55'S × 145°15'E, Wet Sclerophyll, 950m, Sieved litter / QM Reg. No. 69200 (QM).

DIAGNOSIS. Immediately distinguished from all other speeies by the distinetly mieroretieulate but not eanalieulate elytra.

DESCRIPTION. *Measurements* (Table 1). Length: 5.9mm; width: 2.25mm. Ratios. Length eye/orbit: 2.3; width/length of pronotum: 1.22; width widest diameter/base of pronotum: 1.32; width pronotum/

head: 1.23; length/width of elytra: 1.47; width elytra/pronotum: 1.44.

Colour. (Fig. 3B) Upper surface unicolourous black, though labrum and apical half of clypeus red. Apical part of margin of pronotum and lateral margins of elytra narrowly red. Epipleurae of elytra red. Palpi, antennae, and legs light red.

Head. Large, with fairly large, moderately protruding eyes that are almost 2.5 times length of orbits. Mentum with acute median tooth. Labial palpus in ♂ markedly securiform, that of ♀ unknown. Antenna short, just attaining base of pronotum. Upper surface with coarse and dense punctation and coarse longitudinal strioles. Apparently no microreticulation present. Surface very glossy.

Pronotum. Comparatively narrow, cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Most of disc rather densely and coarsely punctate and with transverse strioles. At apex, base and near lateral margin punctation even coarser and denser. No traces of microreticulation visible, surface highly glossy.

Elytra. Moderately wide, depressed, widest at middle. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, barely crenulate. Intervals slightly convex, median ones almost depressed, each with an irregular row of rather coarse punctures and with superficial though distinct, more or less isodiametric microreticulation, surface opaque though moderately glossy. 3rd interval bipunctate, punctures coarse, the anteror one situated in middle of interval slightly in front of middle, the posterior one situated near 3rd stria at apical third, but location rather irregular.

Ventral surface. Prosternum and proepisternum rather coarsely punctate, the latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate.

Male genitalia. (Fig. 2G) Rather large in comparison to body size. Genital ring moderately wide, slightly convex, almost symmetric. Base rather deep. Aedeagus comparatively narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface very slightly concave, apex elongate, straight, very slightly widened at tip. Parameres very dissimilar, asetose, left one large, elongate, rather triangular, right one small, moderately elongate.

Variation. Unknown.

COLLECTING CIRCUMSTANCES. Sieved from montane wet sclerophyll forest litter at a fairly high altitude of about 950m.

DISTRIBUTION. (Fig. 10) Hann Tableland west of Cairns, north-eastern Queensland. Known only from the type locality.

RELATIONSHIPS. This is a fairly isolated species within the *papua*-group, but is probably most closely related to *H. monteithi* sp. nov.

Habutarus monteithi sp. nov.
(Figs 3C, 2H, 10)

ETYMOLOGY. The name is a patronym in honour of the collector of the holotype.

MATERIAL. HOLOTYPE: ♂, Lake Boronto (=Wincheura), Newcastle Bay, C. York, Qld. Jan30-Feb 4. 1975, G. B. Monteith, Rainforest / Pitfall Trap No. 3/1+3 QMT123615 (QM). PARATYPE: 1♀, 12.43S 143.17E 9km ENE of Mt Tozer QLD5-10 July 1986 T. Weir / Berlesate ANIC. 1060 rainforest litter (ANIC).

DIAGNOSIS. Medium-sized species with highly iridescent elytra. Distinguished from *H. convexipennis* sp. nov. by longer elytra; from *H. punctatipennis* sp. nov. and *H. chillagoensis* sp. nov. by far less coarse punctation of the elytral intervals; from *H. weiri* sp. nov. by a more cordiform pronotum bearing a narrower base and by its smaller size; from *H. calderi* sp. nov. by a wider pronotum and barely punctate head; and from *H. kirramae* sp. nov. by its smaller size and much wider pronotum.

DESCRIPTION. *Measurements* (Table I). Length: 5.3-5.4mm; width: 2.0-2.1mm. Ratios. Length eye/orbit: 2.3-2.4; width/length of pronotum: 1.25-1.27; width widest diameter/base of pronotum: 1.39-1.41; width pronotum/head: 1.26-1.27; length/width of elytra: 1.49-1.50; width elytra/pronotum: 1.42-1.44.

Colour. (Fig. 3C) Head and pronotum black, elytra faintly lighter, very dark piceous, distinctly sericeous. Labrum and clypeus dark red. Anterior part of lateral margins of pronotum and lateral

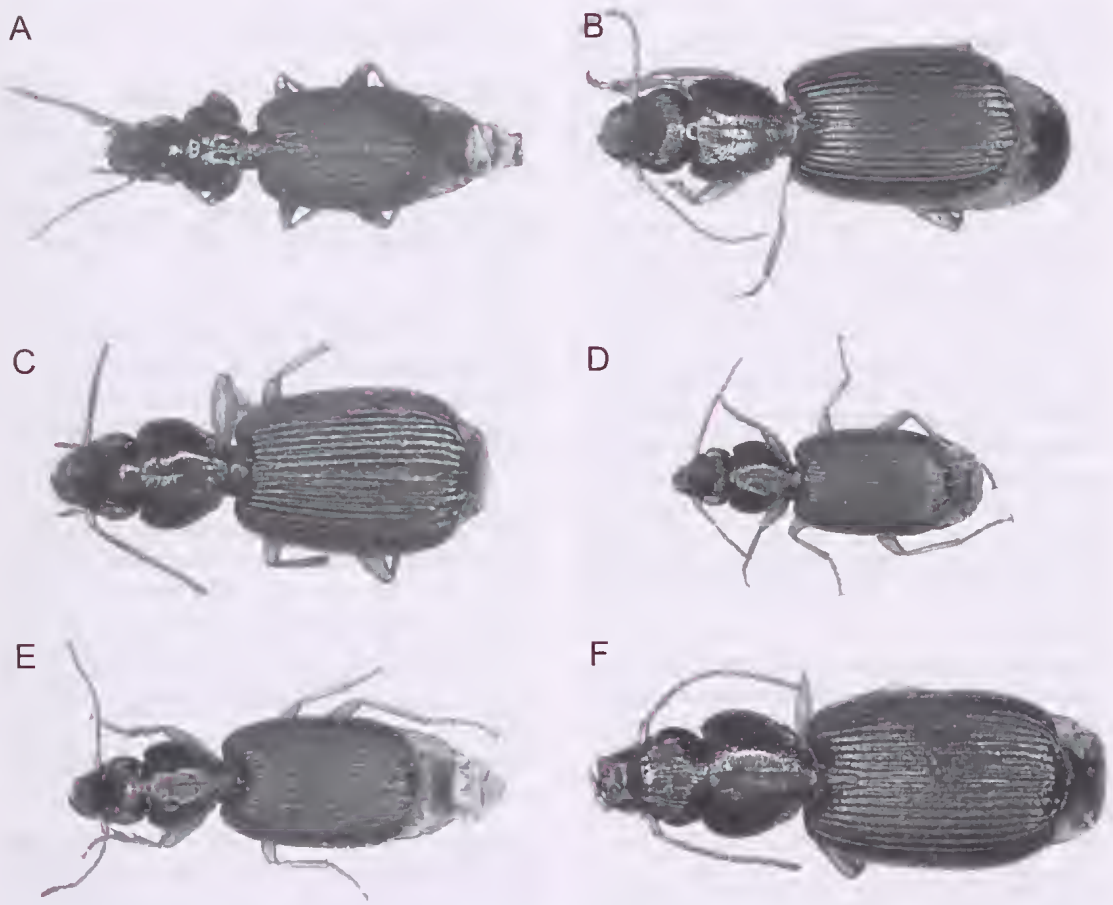

FIG. 3. Dorsal views of *Habutarus* spp. (body length in brackets). A, *H. rugosipennis* sp. nov. (5.0mm); B, *H. opacipennis* sp. nov. (5.9mm); C, *H. monteithi* sp. nov. (5.3mm); D, *H. punctatipennis* sp. nov. (6.0mm); E, *H. chillagoensis* sp. nov. (5.65mm); F, *H. weiri* sp. nov. (5.9mm).

margin of elytra narrowly red. Epipleura red. Palpi, antennae, and legs light red.

Head. Large, with fairly large, moderately protruding eyes that are about 2.5 times length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ very securiform. Antenna short, just attaining base of pronotum. Upper surface near eyes with a few coarse longitudinal strioles that end in front of posterior margin of eyes. Centre of frons and vertex with very sparse, moderately coarse punctures but without any strioles. No microreticulation visible. Surface very glossy.

Pronotum. Wide and cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Most of disc very sparsely and finely punctate, almost glossy, without transverse strioles. Only at apex, base and near lateral margin punctation coarser and denser and with rather superficial transverse strioles. No traces of microreticulation visible, surface very glossy.

Elytra. Moderately wide and depressed, very little widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, rather coarsely punctate-crenulate. Intervals fairly convex, each with an irregular row of moderately fine

punctures that is quite difficult to detect, without any microreticulation. Surface very glossy, highly iridescent. 3rd interval bipunctate, punctures coarse, though difficult to detect, situated in middle of interval or near 3rd stria, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum barely punctate, proepisternum sparsely punctate and pilose; mesothorax, metathorax, and abdomen almost impunctate, whole lower surface very glossy.

Male genitalia. (Fig. 2H) Rather large in comparison to body size. Genital ring moderately wide, only at apex slightly asymmetric. Base moderately deep. Aedeagus narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface slightly concave, apex fairly elongate, straight, rather acute at tip. Parameres very dissimilar, asetose, left one large, elongate, irregularly triangular, right one small, moderately elongate.

Variation. Apart from some differences in colouration that may be due to the teneral condition of the holotype, very little variation was noted.

COLLECTING CIRCUMSTANCES. Collected by pitfall trap and by Berlese extraction of litter in rainforest.

DISTRIBUTION. (Fig. 10) Northern and central Cape York Peninsula from Iron Range to Cape York, northern Queensland.

RELATIONSHIPS. Probably less closely related to the following four species than these *inter se*.

Habutarus punctatipennis sp. nov.
(Figs 3D, 5A, 10)

ETYMOLOGY. The name refers to the coarse punctation of the elytral intervals.

MATERIAL. HOLOTYPE: ♂, Cairns NQ 10/50 GB. / M. 236 / species. det. B. P. Moore'69 / J. G. Brooks Bequest, 1976 (ANIC). PARATYPES: 1♀, Cairns. NQ. 10/51 GB. / *crassiceps* Macl. 1457. / *Nototarus* Chaud. 875. / J. G. Brooks Bequest, 1976 (ANIC); 1♀, Davies Creek. NQ 10/50 GB / J. G. Brooks Bequest, 1976 (CBM).

DIAGNOSIS. Medium-sized species with highly iridescent elytra. Distinguished from *H. convexipennis* sp. nov. by longer elytra and a narrower pronotum; from all other species apart from *H. chillagoensis* sp. nov. by the coarse punctation of the elytral intervals; from *H. chillagoensis* by slightly its larger size and anteriorly wider pronotum.

DESCRIPTION. *Measurements* (Table 1). Length: 6.0-6.1mm; width: 2.25-2.30mm. Ratios. Length eye/orbit: 2.0-2.2; width/length of pronotum: 1.19-1.22; width widest diameter/base of pronotum: 1.32-1.33; width pronotum/head: 1.21-1.25; length/width of elytra: 1.50-1.51; width elytra/pronotum: 1.45-1.49.

Colour. (Fig. 3D) Head and pronotum black, elytra very faintly lighter, very dark piceous, highly sericeous. Labrum and apical half of clypeus dark red. Lateral margins of elytra narrowly red. Epipleura red. Palpi, antennae, and legs light red.

Head. Large, with fairly large, moderately protruding eyes that are about twice length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ markedly securiform. Antenna short, just attaining base of pronotum. Upper surface densely and coarsely punctate and with rather dense, coarse longitudinal strioles near eyes. Centre of frons without strioles but coarsely punctate, vertex with some irregular, coarse strioles. No microreticulation visible. Surface very glossy.

Pronotum. Wide and cordiform, surface depressed. Apex moderately excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface densely and coarsely punctate and striolate, lateral parts with coarser and even denser punctation and with even denser transversal strioles. No traces of microreticulation visible, surface very glossy.

Elytra. Rather elongate, depressed, widest in middle though laterally almost parallel. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, rather coarsely punctate-crenulate. Intervals fairly convex, each with a clearly visible, irregular row of coarse punctures, without any microreticulation. Surface very glossy, highly iridescent. 3rd interval bipunctate, punctures coarse, though difficult to detect, situated in middle of interval or near 3rd stria, the anterior

one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum barely punctate, proepisternum sparsely punctate and pilose; mesothorax, metathorax, and abdomen almost impunctate, whole lower surface very glossy.

Male genitalia. (Fig. 5A) Rather large in comparison to body size. Genital ring rather narrow, only at apex slightly asymmetric. Base rather deep. Aedeagus comparatively narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface straight, apex rather short, straight, slightly obtuse. Parameres very dissimilar, asetose, left one large, elongate, irregularly triangular, right one small, moderately elongate.

Variation. Apart from slight differences in the relative width of the pronotum, very little variation was noted.

COLLECTING CIRCUMSTANCES. Unknown, but based on the collection localities, probably a rainforest dwelling species.

DISTRIBUTION. (Fig. 10) Vicinity of Cairns, north-eastern Queensland.

RELATIONSHIPS. In view of its shape and structure, this species is most closely related to *H. chillagoensis* sp. nov. from inland northern Queensland.

Habutarus chillagoensis sp. nov.
(Figs 3E, 5B, 11)

ETYMOLOGY. The name refers to the type locality, the town of Chillagoe.

MATERIAL. HOLOTYPE: ♂, QLD, 2km W of Chillagoe 330m, 28/6/71 Deeid. Vine Thicket /Berlesate ANIC. 341 Taylor Feehan 17.14x144.30 (ANIC).

DIAGNOSIS. Medium-sized species with highly iridescent elytra. Distinguished from *H. convexipennis* sp. nov. by longer elytra and a narrower pronotum; from all other species apart from *H. punctatipennis* sp. nov. by coarse punctation of the eltral intervals; from *H. punctatipennis* sp. nov. by slightly smaller size and anteriorly narrower pronotum.

DESCRIPTION. *Measurements* (Table 1). Length: 5.65mm; width: 2.15mm. Ratios. Length eye/orbit: 2.05; width/length of pronotum: 1.22; width widest diameter/base of pronotum: 1.29; width pronotum/head: 1.26; length/width of elytra: 1.51; width elytra/pronotum: 1.48.

Colour. (Fig. 3E) Head and pronotum black, elytra very faintly lighter, very dark piceous, highly sericeous. Labrum and apical half of clypeus dark red. Lateral margins of elytra narrowly red. Epipleura red. Palpi, antennae, and legs light red.

Head. Large, with fairly large, moderately protruding eyes that are about twice length of orbits. Mentum with acute median tooth. Labial palpus in ♂ highly securiform, that of ♀ unknown. Antenna short, just attaining base of pronotum. Upper surface densely and coarsely punctate and with rather dense, coarse longitudinal strioles near eyes. Centre of frons without strioles but coarsely punctate, vertex with some irregular, coarse strioles. No microreticulation visible. Surface very glossy.

Pronotum. Moderately wide, cordiform, surface depressed. Apex moderately excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface densely and coarsely punctate and striolate, lateral parts with coarser and even denser punctation and with even denser transverse strioles. No traces of microreticulation visible, surface very glossy.

Elytra. Rather elongate, depressed, widest in middle though laterally almost parallel. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, rather coarsely punctate-crenulate. Intervals fairly convex, each with a clearly visible, irregular row of coarse punctures, without any microreticulation. Surface very glossy, highly iridescent. 3rd interval bipunctate, punctures coarse, though difficult to detect, situated in middle of interval or near 3rd stria, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum barely punctate, proepisternum sparsely punctate and pilose; mesothorax, metathorax, and abdomen almost impunctate, whole lower surface very glossy.

Male genitalia. (Fig. 5B) Rather large in comparison to body size. Genital ring narrow,

almost symmetric, though apex angulate and asymmetric. Base moderately deep. Aedeagus comparatively narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface very slightly concave, apex narrow and elongate, rather acute at tip. Parameres very dissimilar, asetose, left one large, wide, irregularly triangular, right one small, rather short.

Variation. Unknown.

COLLECTING CIRCUMSTANCES. The holotype was colleted by Berlese sampling of ground litter in deciduous vine forest at rather low altitude.

DISTRIBUTION. (Fig. 11) Vicinity of Chillagoe, northern Queensland west of the Great Dividing Range. Known only from the type locality.

RELATIONSHIPS. Most closely related to *H. punctatipennis* sp. nov. from coastal northern Queensland.

Habutarus weiri sp. nov.
(Figs 3F, 5C, 11)

ETYMOLOGY. The name is a patronym in honour of the collector.

MATERIAL. HOLOTYPE: ♂, 13.44S 143.20E QLD 11km WbyN of Bald Hill, McIlwraith Range, 27 June-12 July 1989, T. A. Weir, 520m, search party campsite / Berlesate ANIC 1118 leaf litter closed forest (ANIC). PARATYPES: 2♀, same data (ANIC, CBM).

DIAGNOSIS. Medium-sized species with highly iridescent elytra. Distinguished from *H. convexipennis* sp. nov. by longer elytra; from *H. punctatipennis* sp. nov. and *H. chillagoensis* sp. nov. by the far less coarse punctation of the elytral intervals; from *H. monteithi* sp. nov. by a less cordiform pronotum bearing a wider base, larger size, and the much denser punctation and striolation of the head; from *H. calderi* sp. nov. by a wider pronotum, particular relativel to the head, but with a comparatively wider base; and from *H. kirramae* sp. nov. by smaller size and a wider pronotum.

DESCRIPTION. *Measurements* (Table 1). Length: 5.9-6.1mm; width: 2.2-2.3mm. Ratios. Length eye/orbit: 2.1-2.3; width/length of pronotum: 1.24-1.27; width widest diameter/base of pronotum: 1.30-1.33; width pronotum/head: 1.28-1.31; length/width of elytra: 1.46-1.51; width elytra/pronotum: 1.40-1.42.

Colour. (Fig. 3F) Uniformly black, elytra not lighter, highly sericeous. Labrum and apical half of clypeus dark red. Anterior part of lateral margins of pronotum and lateral margin of elytra very narrowly red. Epipleura red. Palpi, antennae, and legs light red.

Head. Large, with fairly large, moderately protruding eyes that are about twice length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ strongly securiform. Antenna short, just surpassing base of pronotum. Whole upper surface coarsely punctate and with very coarse longitudinal strioles extending over whole length of frons and vertex. On centre of frons traces of extremely superficial isodiametric microretieulation visible at high magnification. Surface very glossy.

Pronotum. Wide and cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions laeking. Lateral margin narrow throughout. Disc densely and coarsely punctate and more or less densely striolate, laterally punctures and strioles even denser and coarser. No traces of microreticulation visible, surface very glossy.

Elytra. Moderately wide and depressed, very little widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly exeised. Lateral channel narrow. Striae impressed, eomplete, moderately deep, rather coarsely punctate-crenulate. Intervals fairly convex, each with an irregular row of moderately fine punctures that is quite difficult to detect, without any mierorctieulation. Surface very glossy, highly irideseent. 3rd interval bipunetate, punetures coarse, though difficult to deteet, situated in middle of interval or near 3rd stria, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum barely punetate, proepisternum sparsely punctate and pilose; mesothorax, metathorax, and abdomen almost impunetate, whole lower surface very glossy.

Male genitalia. (Fig. 5C) Rather large in eomparison to body size. Genital ring moderately narrow, only at apex slightly asymmetric. Base rather deep. Aedeagus comparatively narrow

and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface almost straight, apex short and rather stout, straight, obtuse at tip. Paramcres very dissimilar, asetose, left one large, irregularly triangular, right one small, moderately elongate.

Variation. Very little variation noted apart from slight differences in relative shape and microstrueture of pronotum.

COLLECTING CIRCUMSTANCES. Collected by Berlese extraction of leaf litter in 'closed forest', probably rainforest, at medium altitude.

DISTRIBUTION (FIG. 11). McIlwraith Range, east of Coen, mid Cape York Peninsula, northern Queensland. Known only from the type locality.

RELATIONSHIPS. Based on the structure of the head and pronotum, probably most closely related to *H. calderi* sp. nov. from the vicinity of Cooktown.

Habutarus calderi sp. nov.
(Figs 4A, 5D, 11)

ETYMOLOGY. The name is a patronym in honour of the eollector.

MATERIAL. HOLOTYPE: ♂, 15.03S 145.09E 3km NE of Mt Webb QLD, 30 Apr- 3 May 1981, A. Calder & J. Feehan / Berlesate ANIC 721 rainforest litter (ANIC). PARATYPES: 1♂, 1♀, same data (ANIC, CBM); 1♂, same loeality, 1-3 Oct 1980r / Berlesate ANIC 650 Sieved rain-forest litter (ANIC); 1♀, 15.04S 145.07E Mt Webb NP QLD 27-30 Apr 1981, A. Calder & J. Feehan / Berlesate ANIC 715 rainforest litter (ANIC); 1♀, 15.29S 145.16E, Mt Cook NP QLD, 10-12 May 1981, A. Calder & J. Feehan / Berlesate ANIC 724 *Melaleuca* litter (ANIC).

DIAGNOSIS. Medium-sized species with very iridescent elytra. Distinguished from *H. convexipennis* sp. nov. by longer elytra; from *H. punctatipennis* sp. nov. and *H. chillagoensis* sp. nov. by the far less coarse punctation of the elytral intervals; from *H. monteithi* sp. nov. by a narrower pronotum, in particular relative to head, larger size, and much denser punctation and striolation of the head; from *H. weiri* sp. nov. by a narrower pronotum, in particular relative to the head, but with a comparatively narrower base; and from *H. kirramae* sp. nov. by smaller size and a wider pronotum.

DESCRIPTION. *Measurements.* (Table 1) Length: 4.8-6.0mm; width: 1.9-2.3mm. Ratios. Length eye/orbit: 2.0-2.2; width/length of pronotum: 1.20-1.23; width widest diameter/base of pronotum: 1.34-1.39; width pronotum/head: 1.19-1.25; length/width of elytra: 1.47-1.52; width elytra/pronotum: 1.44-1.52.

Colour. (Fig. 4A) Head blaek, in most speeimens pronotum faintly lighter, dark piceous, and elytra still lighter and piccous or even red-piceous. Elytra highly sericeous. Labrum and clypeus dark red. Anterior part of lateral margins of pronotum and lateral margin of elytra narrowly red. Epipleura red. Palpi, antennae, and legs light red.

Head. Large, with fairly large, moderately protruding eyes that are about 2.5 times length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ strongly securiform. Antenna short, just surpassing base of pronotum. Upper surface coarsely and rather densely punctate and striolate, though strioles in middle of frons less distinct. On centre of frons traces of extremely superficial isodiametric microreticulation visible at high magnification. Surface very glossy.

Pronotum. Wide and cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Most of disc very sparsely and finely punctate, almost glossy, without transverse strioles. Only at apex, base and near lateral margin punctation coarser and denser and with rather superficial transverse strioles. No traces of microreticulation visible, surface very glossy.

Elytra. Moderately wide and depressed, very little widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, rather coarsely punctate-crenulate. Intervals fairly convex, each with an irregular row of moderately fine punctures that are quite difficult to detect, without any microreticulation. Surface very glossy, highly iridescent. 3rd interval bipunctate, punctures coarse, though difficult to detect, situated in middle of interval or near 3rd stria, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum barely punctate, proepisternum sparsely punctate and pilose; mesothorax, metathorax, and abdomen almost impunctate, whole lower surface very glossy.

Male genitalia. (Fig. 5D) Rather large in comparison to body size. Genital ring moderately narrow, only at apex slightly asymmetric. Base rather deep. Aedeagus comparatively narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface almost straight, apex elongate, straight, very slightly widened at tip. Parameres very dissimilar, asetose, left one large, very irregularly triangular, right one small, moderately elongate.

Variation. A rather variable species in body size and in the proportions of pronotum that seems to be narrower in small specimens.

COLLECTING CIRCUMSTANCES. Collected by Berlese extraction of leaf litter in rainforest.

DISTRIBUTION (FIG. 11). Mt Webb and Mt Cook, near Cooktown, north-eastern Queensland.

RELATIONSHIPS. Based on the structure of the head and pronotum, probably most closely related to *H. weiri* sp. nov. from the McIlwraith Range further north.

Habutarus kirramae sp. nov.
(Figs 4B, 5E, 10)

ETYMOLOGY. The name refers to the type locality, Kirrama Range south-west of Tully.

MATERIAL. HOLOTYPE: ♂, Kirrama Range, NE QLD (Mt Smoko turnoff, 600m) 10 Dec 1986 – 11 Jan 1987, Monteith, Thompson & Hamlet, RF, Pitfalls Traps/ QM Reg. No. T22151 / Wetrop databased as ?A*nomotarus* NQ1 (wingless) Temporary label only (QM). PARATYPES: 2♀♀, Kirrama Range, NEQLD (Douglas Ck Rd, 800m) 10 Dec 1986 – 11 Jan 1987, Monteith, Thompson & Hamlet, RF, Pitfalls Traps/ QM Reg. No. T22149-50 / Wetrop databased as ?A*nomotarus* NQ1 (wingless) Temporary label only (CBM, QM).

DIAGNOSIS. Moderately large species with glossy, somewhat iridescent elytra. Distinguished from all other Australian species of the *papua*-group by a combination of larger size, a narrow pronotum bearing extraordinarily narrow lateral margins, very finely punctate elytra, and an almost glabrous head and pronotum.

DESCRIPTION. *Measurements* (Table 1). Length: 6.4-6.9mm; width: 2.4-2.6mm. Ratios. Length eye/orbit: 1.6-1.8; width/length of pronotum: 1.15-1.20; width widest diameter/base of pronotum: 1.33-1.36; width pronotum/head: 1.21-1.25; length/width of elytra: 1.48-1.50; width elytra/pronotum: 1.45-1.52.

Colour. (Fig. 4B) Head and pronotum black, elytra faintly lighter, very dark piceous, highly sericeous. Labrum dark red. Lateral margins of pronotum and elytra not lighter, though epipleura dark red. Palpi, antennae, and legs light red.

Head. Large, dorsally unusually convex, with moderately large, moderately protruding eyes that are less than twice length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex slightly less than half as wide as long, in ♂ strongly securiform. Antenna short, barely attaining base of pronotum. Upper surface near eyes with very few, short, coarse longitudinal strioles that end about at middle of eyes. Centre of frons and vertex with very sparse and fine punctures but without any strioles. No microreticulation visible. Surface very glossy.

Pronotum. Moderately wide, cordiform, surface rather depressed. Apex very slightly excised, base in middle produced. Apical angles little projecting, rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute dentieles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin very narrow throughout. Most of disc very sparsely and finely punctate, almost glossy, without transverse strioles. Only near base and near lateral margins punctation slightly coarser and denser and with superficial transverse strioles. No traces of microreticulation visible, surface very glossy.

Elytra. Moderately wide and depressed, distinctly widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel very narrow. Striae impressed, complete, moderately deep, finely punctate-crenulate. Intervals fairly convex, each with an irregular row of very fine punctures that is visible only at high magnification, without any microreticulation. Surface very glossy, rather iridescent. 3rd interval bipunctate, punctures coarse, situated in middle of interval, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum sparsely and shallowly punctate, proepisternum sparsely punctate and

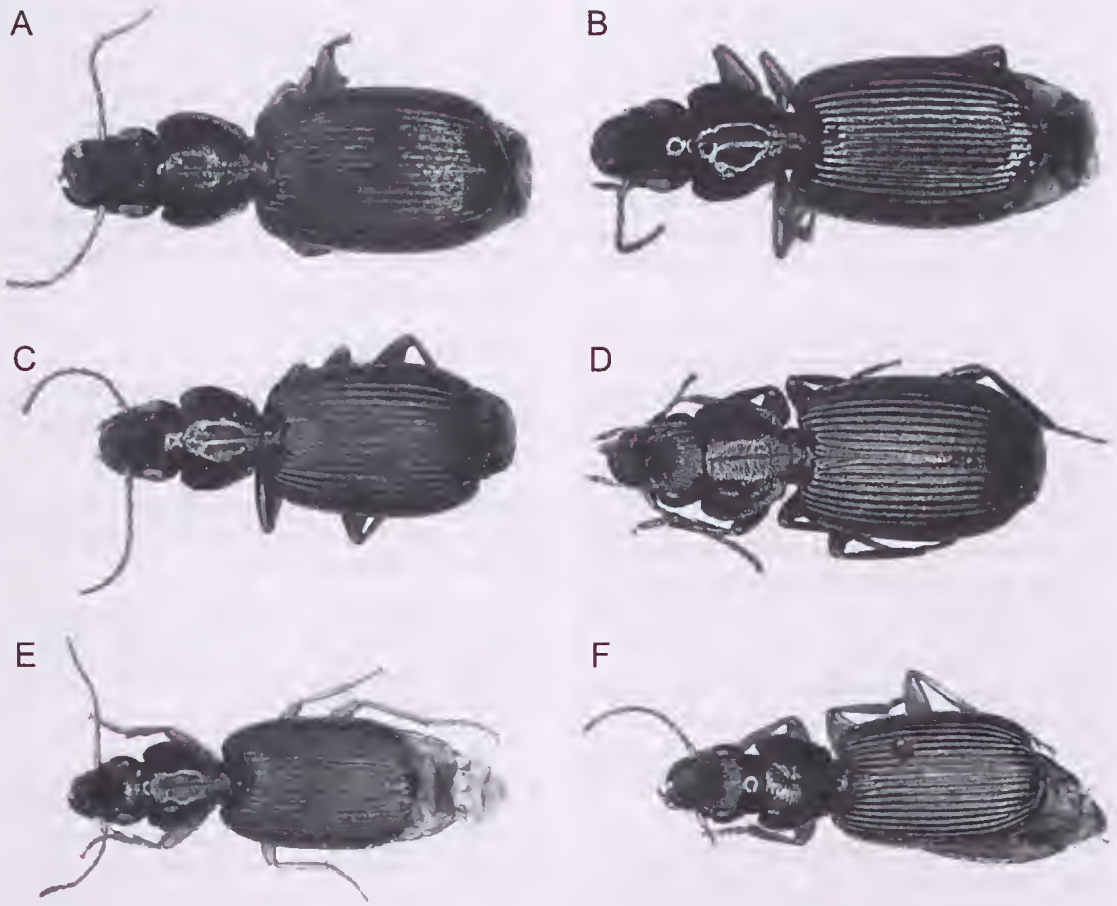

FIG. 4. Dorsal views of *Habutarus* spp. (body length in brackets). A, *H. calderi* sp. nov. (6.0mm); B, *H. kirramae* (6.9mm); C, *H. convexipennis* sp. nov. (5.25mm); D, *H. crassiceps* (Macleay) (8.3mm). E, *H. laticeps* sp. nov. (8.7mm); F, *H. parviceps* sp. nov. (8.6mm).

pilose; mesothorax, metathorax, and abdomen almost impunctate, whole lower surface very glossy.

Male genitalia. (Fig. 5E) Rather large in comparison to body size. Genital ring moderately narrow, only at apex slightly asymmetric. Base rather deep. Aedeagus comparatively narrow and elongate, slightly asymmetric, orifice short, situated on left side. Lower surface almost straight, apex moderately elongate, straight, slightly obtuse at tip. Parameres very dissimilar, asetose, left one large, elongate, irregularly triangular, right one small, moderately elongate.

Variation. Apart from some differences in the relative width of the pronotum, very little variation noted.

COLLECTING CIRCUMSTANCES. Collected in a pitfall trap, in rainforest, at a fairly high altitude of 600-800m.

DISTRIBUTION. (Fig. 10) Kirrama Range, south-west of Tully, north-eastern Queensland. Known only from the type locality.

RELATIONSHIPS. Due to the very weak punctation on all body surfaces, and the extremely narrow lateral margins of the pronotum, this is a rather isolated species within the group of species related to *H. monteithi* sp. nov.

Habutarus convexipennis sp. nov.
(Figs 4C, 10)

ETYMOLOGY. The name refers to the short and comparatively convex elytra.

MATERIAL. HOLOTYPE: ♀, NT Baroalba Ck Gorge, 19km Ex N of Mt Cahill, 16 Nov 1972 R. W. Taylor /Berlesate ANIC. 446 rainforest 12.50S 132.52E (ANIC).

DIAGNOSIS. Rather small species with very iridescent elytra. Distinguished from all other Australian species of the *papua*-group by wider pronotum and shorter and wider elytra.

DESCRIPTION. *Measurements* (Table 1). Length: 5.25mm; width: 2.05mm. Ratios. Length eye/orbit: 2.0; width/length of pronotum: 1.29; width widest diameter/base of pronotum: 1.36; width pronotum/head: 1.29; length/width of elytra: 1.42; width elytra/pronotum: 1.44.

Colour. (Fig. 4C) Head and pronotum black, elytra very faintly lighter, very dark piceous, very sericeous. Palpi and antennae red, legs dirty yellow, but femora with a piceous tint.

Head. Large, with fairly large, moderately protruding eyes that are about twice length of orbits. Mentum with acute median tooth. Apical palpomere of ♀ labial palpus about half as wide as long, that of ♂ unknown. Antenna short, just attaining base of pronotum. Upper surface near eyes with a few coarse longitudinal strioles that end in front of posterior margin of eyes. Centre of frons and vertex with very sparse, moderately coarse punctures but without any strioles. Extremely fine and superficial traces of microreticulation visible in middle under high magnification. Surface very glossy.

Pronotum. Wide and cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Most of disc sparsely and finely punctate, almost glossy, without distinct transverse strioles. Only at apex, base and near lateral margin punctation coarser and denser and laterally with rather dense and distinct transverse strioles. No traces of microreticulation visible, surface very glossy.

Elytra. Rather short and wide, dorsally comparatively convex, slightly widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, deep, coarsely punctate-crenulate. Intervals convex, irregularly impressed laterally by the coarse punctation of striae, each with an irregular row of fine punctures that is extremely difficult to detect, without any microreticulation. Surface very glossy, very iridescent. 3rd interval bipunctate, punctures coarse, though difficult to detect, situated in middle of interval or near 3rd stria, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum barely punctate, proepisternum sparsely punctate and pilose; mesothorax, metathorax, and abdomen almost impunctate, whole lower surface very glossy.

Male genitalia. Unknown.

Variation. Unknown.

COLLECTING CIRCUMSTANCES. The holotype was collected by Berlese sampling in deciduous rainforest of low altitude.

DISTRIBUTION. (Fig. 10) Kakadu National Park, western margin of Arnhem Land, far northern Northern Territory.

RELATIONSHIPS. Related to the species following *monteithi*, in this paper though differing from all by its exceptionally short and virtually impunctate elytra.

CRASSICEPS-GROUP

This is a group of mostly large species that bear a thickly sclerotised aedeagus, usually with a distinctly hook-shaped apex. *Habutarus eungellae* sp. nov. most probably belongs to this group, even though the form of its male genitalia is unknown.

Habutarus crassiceps (Macleay, 1871) comb. nov. (Figs 4D, 5F, 11)

Cymindis crassiceps Macleay, 1871: 84.

Nototarus crassiceps, Sloane 1915: 471; Csiki 1932: 1492; Moore et al. 1987: 307; Lorenz 1998: 471; 2005: 497.

MATERIAL. LECTOTYPE: ♀, Queensland/ *Cymindis crassiceps* Macl. Moreton Bay / HOLOTYPE (ANIC-MMS). NEW MATERIAL: (13 specimens): QUEENSLAND, 2♂♂, 28°08'S × 152°26'E Mt Huntley, 1250m, 29-30 Jan 1993, G. B. Monteith (CBM, QM); 1♂, Bald Mtn. Area via Emu Vale, SE Qld. 22-24 April, 1984, G. Monteith (QM); 2♂♂, SEQ: 26°09'S × 151°55'E, Jack Smith Scrub, 26 Nov 1995, 500m G. B. & S. R. Monteith (CBM, QM); 1♂, AUST: QM: SE: Perry's Knob, 15 May 1999, G. B. Monteith / QM Berlesate 994, 29°36'S × 152°36'E, Vine Scrub, 200m (QM); 1♂, Little Yabba Ck. B/1 via Kenilworth, SE Qld., G. B. & S. R. Monteith (QM); 1♀, Brooyar Fire Tower, via Gympie, SE Qld. 1975-1976. 457m, A/1 G. B. & S. R. Monteith (QM); 1♂, Tambourine (=Tamborine) 5/5728 / E. Sutton Collection, Don. – Dec 1964 (QM); 1♀, NP, Q., H. Hacker. Dec 1919 / Det. (?) Sloane

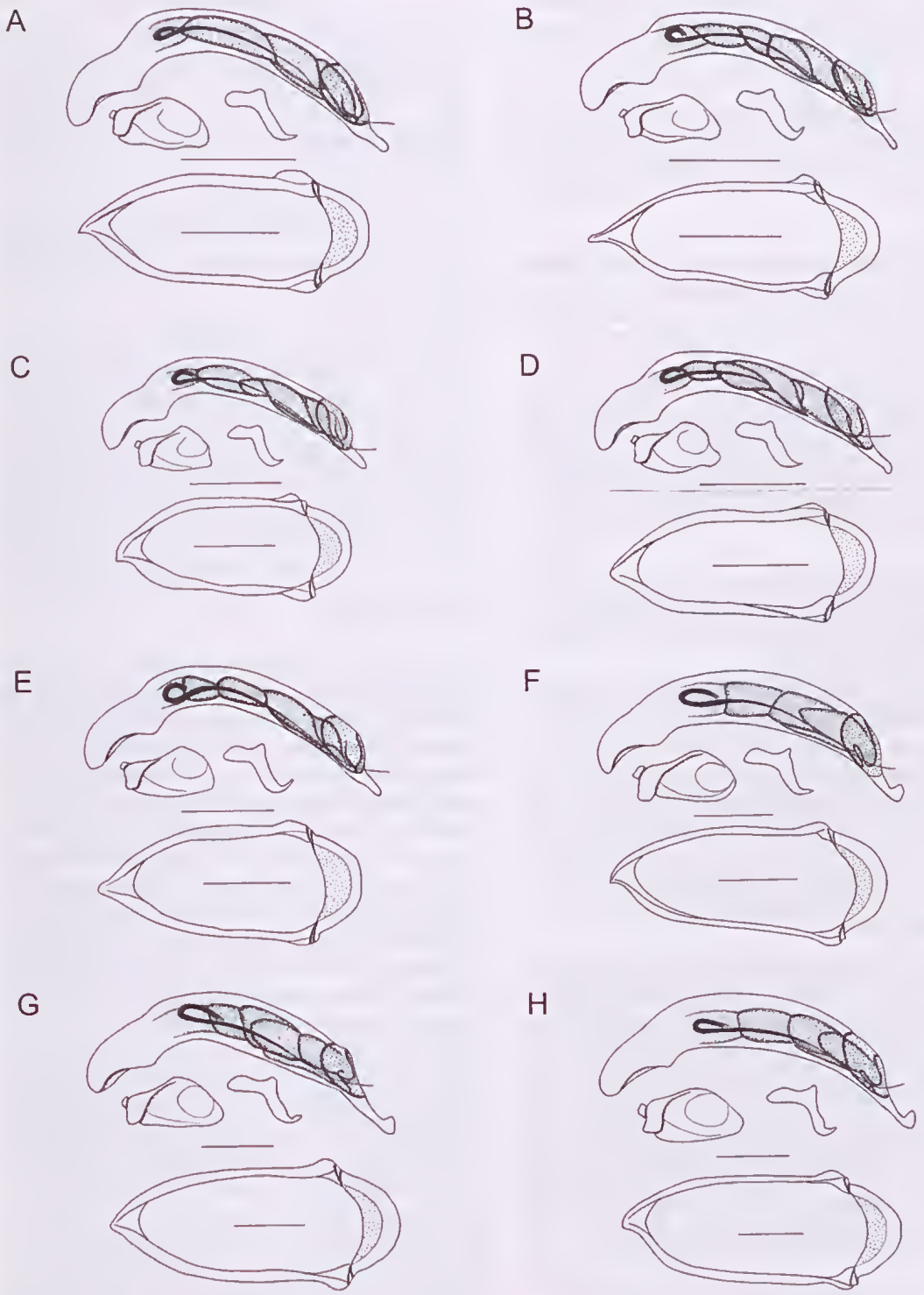

FIG. 5. Male genitalia of *Habutarus* spp. showing aedeagus (upper), parameres (centre) and genital ring (lower), scale 0.5mm. A, *H. punctatipennis* sp. nov.; B, *H. chillagoensis* sp. nov.; C, *H. weiri* sp. nov.; D, *H. calderi* sp. nov.; E, *H. kirramae* sp. nov.; F, *H. crassiceps* (Macleay); G, *H. laticeps* sp. nov.; H, *H. parviceps* sp. nov.

(QM); 1♂, Thunderbird Park, Tamborine Mtn QLD, 24-29 Oct 1993, S. A. Slipinski & J. F. Lawrence, colls (ANIC); 2♀♀ (partly destroyed), K13144 / *Cymindis crassiceps* Macl. Gayndah. Q. (AMS).

NOTE. Although Moore et al. (1987) said that syntype(s) were only located in the Macleay type collection of the ANIC, two old specimens from Gayndah in AMS might belong to the type series.

DIAGNOSIS. Large black species, immediately recognised by the dark legs and the very coarse and dense striolation of the head and the punctation of the pronotum.

DESCRIPTION. *Measurements* (Table 1). Length: 6.8-8.4mm; width: 2.8-3.45mm. Ratios. Length eye/orbit: 1.5-2.2; width/length of pronotum: 1.29-1.37; width widest diameter/base of pronotum: 1.36-1.44; width pronotum/head: 1.26-1.32; length/width of elytra: 1.37-1.45; width elytra/pronotum: 1.35-1.44.

Colour. (Fig. 4D) Unicolourous black, though elytra with more or less distinct violaceous lustre. Palpi and antennae red. Legs black, sometimes tibiae piceous, tarsi red.

Head. Large, with large, moderately protruding eyes that are about 3 times length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ remarkably securiform. Antenna short, just attaining base of pronotum. Upper surface completely covered by very coarse and dense longitudinal strioles that are mixed with coarse punctures. Only superficial traces of isodiametric microreticulation visible. Surface glossy.

Pronotum. Wide and cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute dentieles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface completely covered by very coarse punctures and transverse strioles. Microreticulation absent, surface glossy.

Elytra. Wide and moderately depressed, slightly widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, finely crenulate. Intervals convex, each with an irregular row of fine punctures and with very distinct, isodimateric microreticulation, surface moderately dull. 3rd interval bipunctate, punctures coarse, situated in about centre of interval, the anterior one slightly in front of middle, the posterior one at apical quarter.

Ventral surface. Prosternum and proepisternum coarsely punctate, the latter also sparsely pilose; mesothorax, metathorax, and abdomen more finely punctate.

Male genitalia. (Fig. 5F) Rather large in comparison to body size. Genital ring narrow, almost symmetric, though apex angulate and asymmetric. Base moderately deep. Aedeagus comparatively compact, slightly asymmetric, orifice short, situated on left side. Lower surface very slightly concave, apex comparatively short, with strong somewhat club-shaped apical hook that is slightly directed to right side. Parameres very dissimilar, asetose, left one large, wide, rather triangular, right one small, elongate.

Variation. This species varies significantly in size, relative shape of the pronotum and elytra, and the distinctiveness of the elytral microreticulation. Both specimens from Jack Smith Scrub near Gympie are smaller than usual, have more distinctly punctate elytra that possess a much more superficial microreticulation and also a distinct violaceous lustre. The apex of their aedeagi is slightly shorter than in specimens from Main Range. Surface structures of head and pronotum, however, are very similar in all specimens. Although populations may differ, the picture is not yet clear and any taxonomic and nomenclatorial decisions should be postponed until additional material is at hand.

COLLECTING CIRCUMSTANCES. Largely unknown, though one specimen was collected from 'Vine Scrub, Sieved litter' and two others in 'pitfall' and in 'Rainforest Pitfall'. The altitude range in labelled specimens is from 200 to 1250m.

DISTRIBUTION. (Fig. 11) From the environs of Gympie, in the north, to Main Range near the Queensland/New South Wales border, in the south.

RELATIONSHIPS. Most closely related to the central Queensland species *H. laticeps* sp. nov. and *H. parviceps* sp. nov.

Habutarus laticeps sp. nov.
(Figs 4E, 5G, 10)

ETYMOLOGY. The name refers to the relatively wide head.

MATERIAL. HOLOTYPE: ♂, QUEENSLAND, Kroombit Tops, 45km SSW Calliope, 11. Dec 1983, Monteith, Davies, Gallon & Thompson / QM Berlesate No. 627, Site 11, 24.22S × 150.56E, Open forest, 880m, Sieved litter QMT123614 (QM).

DIAGNOSIS. Large species, distinguished from the equally large and most similar species *H. crassiceps* by its light coloured legs, and from *H. parviceps* by a wider pronotum, shorter and wider elytra, the distinct punctation of the elytral intervals, and smaller eyes.

DESCRIPTION. *Measurements* (Table 1). Length:8.7mm; width: 3.3mm. Ratios. Length eye/orbit: 1.4; width/length of pronotum: 1.27; width widest diameter/base of pronotum: 1.35; width pronotum/head: 1.24; length/width of elytra: 1.43; width elytra/pronotum: 1.40.

Colour. (Fig. 4E) Unicolourous black. Palpi and antennae red. Legs light red.

Head. Large, with moderately large, fairly protruding eyes that are about 1.5 times length of orbits. Mentum with acute median tooth. Labial palpus in ♂ remarkably securiform. Antenna short, just attaining base of pronotum. Upper surface completely covered by very coarse and dense longitudinal strioles that are mixed with coarse punctures. No microreticulation perceptible. Surface highly glossy.

Pronotum. Wide and cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute dentieles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface completely covered by very coarse punctures and transverse strioles. Microreticulation absent, surface glossy.

Elytra. Wide and moderately depressed, slightly widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, finely crenulate. Intervals convex, each with two irregular rows of moderately coarse punctures and with very distinct, isodimaterie microreticulation, surface moderately dull. 3rd interval bipunctate, punctures coarse, situated about in centre of interval, the anterior one slightly in front of middle, the posterior one at apical quarter.

Ventral surface. Prosternum and proepisternum coarsely punctate, the latter also sparsely pilose; mesothorax, metathorax, and abdomen more finely punctate.

Male genitalia (Fig. 5G). Rather large in comparison to body size. Genital ring narrow, almost symmetric, even at apex. Base moderately deep. Aedeagus comparatively compact, slightly asymmetric, orifice short, situated on left side. Lower surface almost straight, in apical part slightly concave, apex comparatively elongate, with strong somewhat club-shaped apical hook that is slightly directed to right side. Parameres very dissimilar, asetose, left one large, wide, rather triangular, right one small, elongate.

Variation. Unknown.

COLLECTING CIRCUMSTANCES. The holotype was collected by Berlese sampling in open forest at a rather high altitude of almost 900m.

DISTRIBUTION. (Fig. 10) Kroombit Tops, central eastern Queensland. Known only from the type locality.

RELATIONSHIPS. Most closely related to the southern *H. crassiceps* and the northern *H. parviceps* sp. nov.

Habutarus parviceps sp. nov.
(Figs 4F, 5H, 11)

ETYMOLOGY. The name refers to the relatively small head.

MATERIAL. HOLOTYPE: ♂, C.QLD: 21°52'S × 149°18'E, Upper Hall Ck. Via Carmila, 4 Dec 96-6 Apr 1997, G. Monteith & E. Mulder, Pitfalls, RF at creek QMT123618 (QM).

DIAGNOSIS. Large species, distinguished from the equally large and most similar species *H. crassiceps* by the light coloured legs, and from *H. laticeps* sp. nov. by a narrower pronotum, longer and narrower elytra, impunctate intervals, and larger eyes.

DESCRIPTION. *Measurements* (Table 1). Length: 8.6mm; width: 3.2mm. Ratios. Length eye/orbit: 2.5; width/length of pronotum: 1.24; width widest diameter/base of pronotum: 1.37; width pronotum/

head: 1.21; length/width of elytra: 1.50; width elytra/pronotum: 1.41.

Colour. (Fig. 4F) Unicolourous black, only margin of pronotum anteriorly very narrowly red. Palpi and antennae red. Legs light red.

Head. Moderately large, with rather large, moderately protruding eyes that are about 2.5 times length of orbits. Mentum with acute median tooth. Labial palpus in ♂ remarkably securiform. Antenna short, just attaining base of pronotum. Upper surface completely covered by very coarse and dense longitudinal strioles that are mixed with coarse punctures. No traces of microreticulation visible. Surface highly glossy.

Pronotum. Moderately wide, cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface completely covered by very coarse punctures and transverse strioles but that are less deep that in related species. Microreticulation absent, surface highly glossy.

Elytra. Comparatively elongate, moderately depressed, barely widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, finely crenulate. Intervals convex, each with an irregular row of very fine punctures and with very distinct, isodimateric microreticulation, surface moderately dull. 3rd interval bipunctate, punctures coarse, situated near 3rd stria, the anterior one slightly in front of middle, the posterior one at apical quarter.

Ventral surface. Prosternum and proepisternum coarsely punctate, the latter also sparsely pilose; mesothorax, metathorax, and abdomen barely punctate.

Male genitalia. (Fig. 5H) Rather large in comparison to body size. Genital ring narrow, almost symmetric, though apex angulate and asymmetric. Base moderately deep. Aedeagus comparatively compact, slightly asymmetric, orifice short, situated on left side. Lower surface slightly concave throughout, apex fairly elongate, with strong somewhat club-shaped apical hook that is slightly directed to right side. Parameres very dissimilar, asetose, left one large, wide, rather triangular, right one small, elongate.

Variation. Unknown.

COLLECTING CIRCUMSTANCES. The holotype was collected by pitfall trapping in rainforest at an unknown altitude.

DISTRIBUTION (FIG. 11). Vicinity of Carmila, central eastern Queensland. Known only from the type locality.

RELATIONSHIPS. Most closely related to the southern species *H. crassiceps* and *H. laticeps* sp. nov.

Habutarus abboti sp. nov.
(Figs 6A, 7A, 10)

ETYMOLOGY. The name refers to the type locality, Mt Abbot west of Bowen.

MATERIAL. HOLOTYPE: ♂, C. QLD: 20°06'S × 147°45'E, Mt Abbot, 800-1000m, 9-12 April 1997, Monteith, Cook & Janetzki QMT123610 (QM). PARATYPES: 1♀, same data (CBM); 1♀, C. QLD: 20°06'S × 147°45'E, Mt Abbot, RF Gully, 10 Apr 1997, G. Monteith, Pyrethrum, trees & rocks (QM).

DIAGNOSIS. Medium-sized species, distinguished from the three previous species by its smaller size and less coarsely sculptured pronotum. Distingushed from the similar-sized species *H. nitidicollis* sp. nov. by a densely punctate and striolate pronotum and distinctly reticulate elytra, from *H. iridipennis* sp. nov. by its dark colour and non-iridescent elytra, and from all three previous species by thickened but not obviously hooked apex of aedeagus.

DESCRIPTION. *Measurements* (Table 1). Length: 6.0-6.3mm; width: 2.30-2.45mm. Ratios. Length eye/orbit: 2.5-2.6; width/length of pronotum: 1.26-1.30; width widest diameter/base of pronotum: 1.38-1.39; width pronotum/head: 1.27-1.28; length/width of elytra: 1.39-1.42; width elytra/pronotum: 1.43-1.48.

Colour. (Fig. 6A) Head and pronotum black, lateral margins narrowly red, elytra very slightly lighter, dark piceous, lateral margins narrowly red. Palpi and antennae red. Legs light red.

Head. Large, with large, moderately protruding eyes that are 2.5 times length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ remarkably securiform. Antenna short, just attaining base of

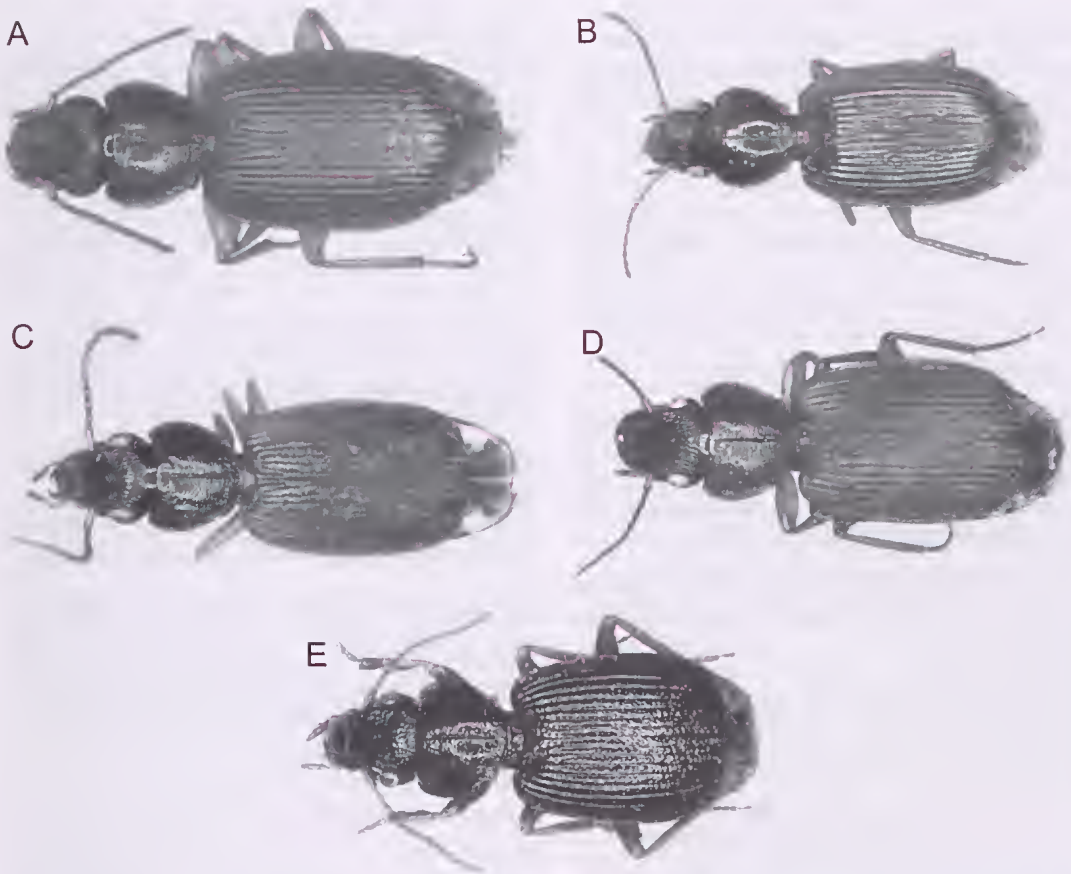

FIG. 6. Dorsal views of *Habutarus* spp. (body length in brackets). A, *H. abboti* sp. nov. (6.3mm); B, *H. nitidicollis* sp. nov. (7.4mm); C, *H. iridipennis* sp. nov. (5.8mm); D, *H. eungellae* sp. nov. (7.0mm); E, *H. pilosus* (Baehr) (6.8mm).

pronotum. Upper surface completely covered by very coarse and dense longitudinal strioles that are mixed with coarse punctures. Only superficial traces of isodiametric microreticulation visible. Surface glossy.

Pronotum. Wide and cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface completely covered by very dense and rather coarse punctures and transverse strioles, but punctures and strioles less deeply impressed than in the three previous species. Superficial traces of microreticulation visible, surface glossy.

Elytra. Wide and moderately depressed, slightly widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, finely crenulate. Intervals convex, with very distinct, isodimateric microreticulation, punctation present but almost invisible within microreticulation, surface dull. 3rd interval bipunctate, punctures coarse, the anterior pair situated about in centre of interval or near 2nd stria and slightly in front of middle, the posterior pair situated near 3rd stria at apical quarter.

Ventral surface. Prosternum and proepisternum with very few, superficial punctures, the latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate.

Male genitalia. (Fig. 7A) Rather large in comparison to body size. Genital ring narrow, almost symmetric, though apex angulate and asymmetric. Base moderately deep. Aedeagus comparatively compact, slightly asymmetric, orifice short, situated on left side. Lower surface almost straight, only near apex very slightly concave, apex comparatively elongate, with somewhat club-shaped but not definitively hook-like tip that is slightly directed to right side. Parameres very dissimilar, asetose, left one large, wide, markedly triangular at apex, right one small, elongate.

Variation. Very little variation noted.

COLLECTING CIRCUMSTANCES. One specimen was sampled by 'Pyrethrum, trees & rocks' which means fogging from boulders and the bases of standing trees. To date known only from remnant rainforest above 800m.

DISTRIBUTION. (Fig. 10) Mt Abbot, west of Bowen, North Queensland. Known only from the type locality.

RELATIONSHIPS. With respect to external morphological characters, more closely related to the three previous species than to the next two.

Habutarus nitidicollis sp. nov.
(Figs 6B, 7B, 11)

ETYMOLOGY. The name refers to the impunctate, glossy pronotum.

MATERIAL. HOLOTYPE: ♂, NEQ: 16°26'S × 145°12'E, Mt Spurgeon Summit 21 Nov 1997. 1320m 1638 Monteith, Cook, Burwell / QM Reg. No. T66696 (QM). PARATYPES: 1♂, NE: Q: 16°24'S × 145°13'E, 3.5km NNE Mt Spurgeon, 15-20 Oct 1991. 1350m, Monteith, Janetzki, Cook & Roberts. PITFALLS / QM Reg. N0. T22159 / Wetrop databased as ?*Anomotarus* NQ3 (wingless) Temporary label only (QM); 1♂, 1♀, Ne. Q: 16°24'S × 145°13'E, Stewart Ck., 4km NNE Mt Spurgeon (Camp 1), 1250-1300m, 15-20 Oct 1991. PITFALLS: Monteith, Cook & Roberts / QM Reg. No. T22157-8 / Wetrop databased as ?*Anomotarus* NQ1 (wingless) Temporary label only (CBM, QM); 1♂, NEQ: 16°24'S × 145°17'E, Upper High Falls Ck, 25 Jan-12 Feb 1996, R. Wertz 1000m, Flight intereept trap / QM Reg. No. T27809 / Wetrop databased as ?*Anomotarus* NQ1 (wingless) Temporary label only (QM); 1♂, Devils Thumb – Paul Luck. 12km WNW Mossman, NQ, 27 Dec 1989 – 15 Jan 1990, ANZSES Expedition Site 11, 1240m, pitfall / QM Reg. No. T22156 / Wetrop databased as ?*Anomotarus* NQ2 (wingless) Temporary label only (QM); 1♂, NE: QLD Devils Thumb, area 10km NW Mossman, 11 Oct 1982, Monteith, Yeates & Thompson / QM Berlesate No 491, 16-34S 145.17E, Rainforest, 1000-1180m, moss on rocks, trees/ QM Reg. No. T22148 / Wetrop databased as ?*Anomotarus* NQ1 (wingless) Temporary label only (QM); 1♂, Mossman Bluff Track, 5-10km W.Mossmann, N. QLD. 20 Dec 1989-15 Jan 1990, Monteith, Thompson & ANZSES Site 10, 1300m, pitfall / QM Reg. No. T22155 / Wetrop databased as ?*Anomotarus* NQ1 (wingless) Temporary label only (QM); 1♀, Mossman Bluff Track, 5-10km W.Mossmann, N. Qld. 17-31 Dec 1988 Monteith, Thompson & ANZSES Site 8, 1180m, pitfall / QM Reg. No. T22154 / Wetrop databased as ?*Anomotarus* NQ1 (wingless) Temporary label only (QM); 1♂, 1♀, Mt Lewis NQ, Jan-Mar 1988, G. Wood, Pitfalls / QM Reg. No. T22152-3 / Wetrop databased as ?*Anomotarus* NQ1 (wingless) Temporary label only (CBM, QM).

DIAGNOSIS. Fairly large species, at once distinguished from all species of the *crassiceps*-group by the glossy, barely punctate pronotum and the head that is sulcate only near the eyes.

DESCRIPTION. *Measurements* (Table 1). Length: 6.6-7.7mm; width: 2.6-3.0mm. Ratios. Length eye/orbit: 1.8-2.0; width/length of pronotum: 1.23-1.28; width widest diameter/base of pronotum: 1.39-1.44; width pronotum/head: 1.23-1.29; length/width of elytra: 1.46-1.50; width elytra/pronotum: 1.41-1.47.

Colour. (Fig. 6B) Head and pronotum black, though labrum and apical half of clypeus red. Apical margin and anterior part of lateral margins of pronotum more-or-less distinctly red. Elytra including epipleura red-piceous to piceous, distinctly lighter than fore body, very glossy. Palpi and antennae red. Legs light red.

Head. Large, with fairly large, moderately protruding eyes that are about twice length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex less than half as wide as long, in ♂ securiform but apex less wide than in related species. Antenna short, just attaining base of pronotum. Upper surface near eyes with coarse and dense longitudinal strioles that end infront of posterior margin of eyes. centre of frons and vertex with sparse, moderately coarse punctures but without any strioles. Superficial, isodiametric microreticulation visible in middle but not laterally. Surface very glossy.

Pronotum. Wide and cordiform, surface depressed. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and

excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Most of dise very sparsely and finely punctate, almost glossy, without transverse strioles. Only at apex, base and near lateral margin punctation coarser and denser. Superficial traces of microreticulation visible at high magnification, surface very glossy.

Elytra. Moderately wide and depressed, widest in middle. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, complete, moderately deep, finely crenulate. Intervals very slightly convex, median ones almost depressed, each with an irregular row of fine punctures and with very superficial, isodiametric microreticulation that is visible only at high magnication, surface glossy. 3rd interval bipunctate, punctures very coarse, somewhat foveate, situated near 3rd stria, the anterior one slightly in front of middle, the posterior one at apical third, but location rather irregular.

Ventral surface. Prosternum and procpisternum very sparsely punctate, the latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate.

Male genitalia. (Fig. 7B) Rather large in comparison to body size. Genital ring narrow, almost symmetric, though apex angulate and asymmetric. Base moderately deep. Aedeagus comparatively narrow and clongate, slightly asymmetrie, orifice short, situated on left side. Lower surface very slightly concave, apex narrow and elongate, with comparatively small, acute, apical hook that is slightly directed to right side. Parameres very dissimilar, asetose, left one large, wide, rather triangular, right one small, very clongate.

Variation. Very little noted, apart from some size differences.

COLLECTING CIRCUMSTANCES. Most specimens were collected in pitfall traps in rainforest with single specimens captured in a 'flight intercept trap' and from 'moss on rocks, trees'. All specimens were collected in montane forest above 1000m elevation, some on the absolute summits of their respective mountains.

DISTRIBUTION. (Fig. 11) Carbine Tableland, northern Queensland.

RELATIONSHIPS. Related to *H. iridipennis* sp. nov. based on colouration, its sericeous lustre, the shape of the setiferous punctures of the elytra, and the shape of the aedeagus.

Habutarus iridipennis sp. nov.
(Figs 6C, 7C, 10)

ETYMOLOGY. The name refers to the iridescent surface of the elytra.

MATERIAL. HOLOTYPE: ♂, NEQ: 16°04'S × 145°25'E Roaring Meg valley, 680m 20-22 Nov 1993. Monteith, Cook, Janetzki & Roberts, pitfall trap / QM Reg. No. T22167 / Wetrop databased as ?*Anomotarus* NQ3 (wingless) Temporary label only (QM). Paratypes. 2♂♂, same data (CBM, QM); 2♂♂, NEQ: 16°03'S × 145°25'E, Mt Halcyon, 870m, 22-24 Nov 1993. Cook, Monteith, Janetzki & Roberts. Pitfalls / QM Reg. No. T22168-9 / Wetrop databased as ?*Anomotarus* NQ3 (wingless) Temporary label only (QM); 1♀, Mt Finnigan Summit Via Helenvale, N.Qld. 3-5 Dec 1990, 1050m, Cook, Thompson & Roberts, Pitfall Traps / QM Reg. No. T22164 / Wetrop databased as ?*Anomotarus* NQ3 (wingless) Temporary label only (QM); 1♀, Mt Finnigan, 37km S Cooktown, N.Qld. 21 Apr1982, Monteith, Yeates & Cook / Q.M. Berlesate No. 410 15.49S, 145.17E, Rainforest, 1050m, Sieved Litter / QM Reg. No. T22162 / Wetrop databased as ?*Anomotarus* NQ3 (wingless) Temporary label only (CBM); 1♀, 2.5km SW Mt Hartley, via Cooktown, N.Qld. 24 Apr1982, Monteith, Yeates & Cook / Q.M. Berlesate No. 400, 15.47S, 145.19E, Rainforest, 610m, Sieved Litter / QM Reg. No. T22163 / Wetrop databased as ?*Anomotarus* NQ3 (wingless) Temporary label only (QM).

DIAGNOSIS. Medium-sized species, at once distinguished from all species of the *crassiceps*-group by the highly iridescent lustre and the large, foveate setiferous punctures of the elytra.

DESCRIPTION. *Measurements* (Table 1). Length: 5.2-6.1mm; width: 2.05-2.40mm. Ratios. Length eye/orbit: 1.7-1.8 (Mt Finnigan area), 2.2-2.3 (Cape Tribulation area); width/length of pronotum: 1.19-1.27; width widest diameter/base of pronotum: 1.38-1.44; width pronotum/head: 1.19-1.26; length/width of elytra: 1.38-1.40 (Mt Finnigan area), 1.43-1.46 (Cape Tribulation area); width elytra/pronotum: 1.46-1.51 (Mt Finnigan area), 1.41-1.46 (Cape Tribulation area).

Colour. (Fig. 6C) Head and pronotum black, though labrum and apical half of clypeus red. Apical margin and anterior part of lateral margins of pronotum more or less distinctly red. Elytra including epipleura red-piceous, basal third and narrow lateral margin red. Elytra conspicuously

lighter than fore body, with remarkably sericeous lustre. Palpi and antennae red. Legs light red.

Head. Large, with fairly large, moderately protruding eyes that are about twice length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long, in ♂ remarkably securiform. Antenna short, just attaining base of pronotum. Upper surface with coarse and dense longitudinal strioles that are shortened in middle of frons, and with coarse punctures. Isodiametrie microreticulation present, though somewhat superficial. Surface moderately glossy.

Pronotum. Moderately wide, cordiform, surface slightly convex. Apex slightly exeised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface rather densely punctate and striolate, though less so in middle of disc. Punctation rather fine and somewhat superfieial. More or less distinct traees of microreticulation visible, surface moderately glossy.

Elytra. Comparatively wide and depressed, widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, though shallow, complete, finely crenulate. Intervals depressed, somewhat irregular, apparently impunetate, but with very fine, irregularly striolate microreticulation that gives the surfaee a highly sericeous lustre. 3rd interval bipunctate, punetures wide, foveate, but shallow, situated near 3rd stria, the anterior one slightly in front of middle, the posterior one at apical third.

Ventral surface. Prosternum and proepisternum very sparsely punctate the latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunetate.

Male genitalia. (Fig. 7C) Rather large in comparison to body size. Genital ring narrow, almost symmetric, though apex angulate and asymmetric. Base moderately deep. Aedeagus comparatively compaet, slightly asymmetric, orifice short, situated on left side. Lower surface very slightly eoneave in basal half, almost straight in apical half, apex narrow and elongate, with comparatively small, acute, apical hook that is slightly direeted to right side. Parameres very dissimilar, asetose, left one large, wide, triangular, right one small, fairly elongate.

Variation. This species shows some variation. Northern speeimens (from Mt Finnigan and Mt Hartley) possess signifieantly smaller eyes and shorter and wider elytra than those from the Cape Tribulation hinterland. These two mountain areas are separated by the valley of the Bloomfield River. It is uncertain, however, whether these differences arc due to geographic or to sexual variation, because all available specimens from near Cape Tribulation are malcs, whereas all northern specimens are females. Males from the Mt Finnigan area are needed to determine whether the northern population represents a separate taxon.

COLLECTING CIRCUMSTANCES. Sampled by pitfall trapping, sieving and Berlese extraction of rainforest litter on mountain tops from 600-1050m elevation.

DISTRIBUTION. (Fig. 10) Mt Finnigan and vicinity and Cape Tribulation area, south of Cooktown, northern Queensland.

RELATIONSHIPS. Based on its colouration, sericeous lustre, and the shape of the setiferous punctures of the elytra, and the shape of aedeagus this species is a close relative of *H. nitidicollis* sp. nov.

Habutarus eungellae sp. nov.
(Figs 6D, 11)

ETYMOLOGY. The name refers to the type locality, the Eungella area of the Clarke Range, west of Mackay.

MATERIAL. HOLOTYPE: ♀, C. Qld: 20°50'S × 148°34'E, Mt Macartney, 900m, 19 Nov 92 – mid April 1993, D. Cook & G. Monteith, RF Intercept & Pitfalls QMT123611 (QM). PARATYPE: 1♀, QLD: 21°02'S × 148°36'E, Upper Cattle Ck, Eungella, 17 Nov 1992, 900m, Monteith, Thompson Cook & Janetzki (CBM).

DIAGNOSIS. A comparatively large species, at once distinguished from all species by the quadripunetate elytra and the yellow, more–or-less distinctly variegated colour pattern.

DESCRIPTION. *Measurements* (Table 1). Length: 7.0-7.2mm; width: 2.85-2.95mm. Ratios. Length eye/orbit: 1.9-2.2; width/length of pronotum: 1.34-1.38; width widest diameter/base of pronotum: 1.38-1.43; width pronotum/head: 1.32; length/

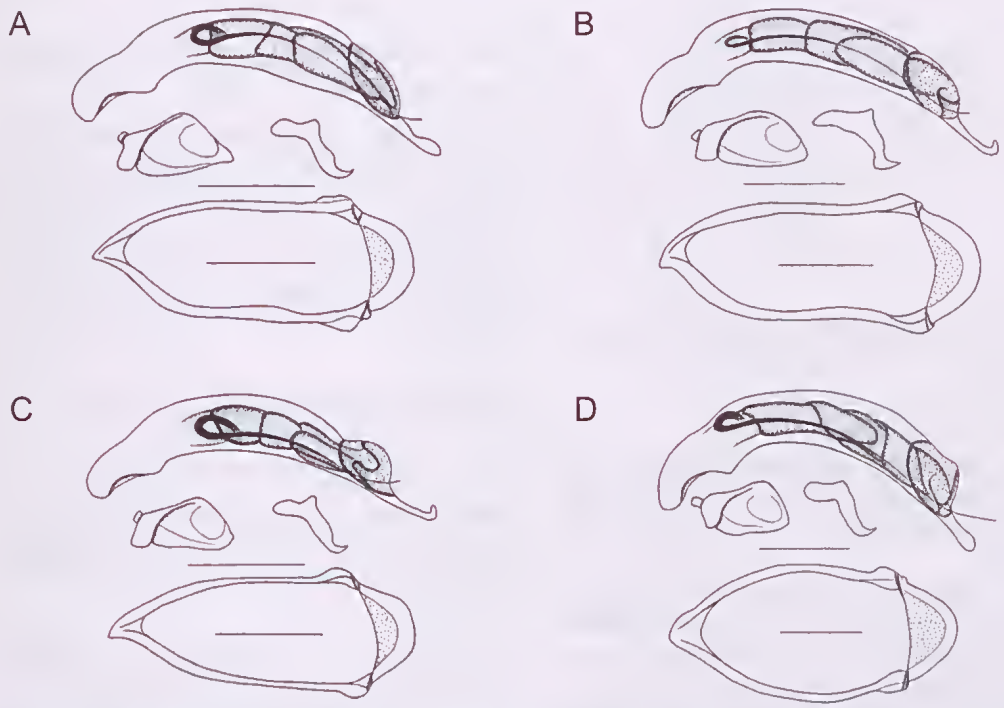

FIG. 7. Male genitalia of *Habutarus* spp. showing aedeagus (upper), parameres (centre) and genital ring (lower), scale 0.5mm. A, *H. abboti* sp. nov.; B, *H. nitidicollis* sp. nov.; C, *H. iridipennis* sp. nov.; D, *H. pilosus* (Baehr).

width of elytra: 1.39-1.41; width elytra/pronotum: 1.39-1.40.

Colour. (Fig. 6D) Head and pronotum black, lateral margins of pronotum narrowly red. Elytra including epipleura light red, with indistinct variegated piceous pattern. Palpi and antennae red. Legs light red.

Head. Large, with fairly large, moderately protruding eyes that are about twice length of orbits. Mentum with acute median tooth. Labial palpus in ♀ at apex about half as wide as long. Antenna short, just attaining base of pronotum. Upper surface with very coarse and dense longitudinal strioles that occupy most of clypeus and extend to neck, and with coarse punctures. Isodiametric microreticulation present and fairly distinct. Surface moderately glossy.

Pronotum. Wide, cordiform, surface slightly convex. Apex slightly excised, base in middle produced. Apical angles projecting though rounded. Lateral margins evenly convex, not sinuate posteriorly but basal angles projecting as minute denticles. Base laterally oblique and excised. Apex not margined in middle, base margined throughout, but in middle margin fine. Median line deep and sulcate. Basal impressions lacking. Lateral margin narrow throughout. Surface very densely punctate, little striolate, punctation in middle of disc less coriaceous than near margins. Punctation moderately coarse. Isodiametric microreticulation distinct, surface rather dull.

Elytra. Comparatively wide and depressed, widened towards apex. Basal angles projecting but evenly rounded. Apical margin oblique, slightly excised. Lateral channel narrow. Striae impressed, though shallow, complete, finely crenulate. Intervals slightly convex, apparently impunctate, but with very distinct, isodiametric microreticulation that gives the surface a very dull appearance. 3rd interval quadripunctate, punctures small, the anterior one situated near 2nd stria in anterior third, the second one in the centre of the interval about in middle, both posterior ones near 3rd interval at apical third.

Ventral surface. Prosternum and proepisternum with very sparse and shallow punctation but distinct microreticulation, the latter also sparsely pilose; mesothorax, metathorax, and abdomen almost impunctate.

FIG. 8. *Habutarus papua* (Darlington), female stylomeres. A, ventral view. B, median view (scale: 0.1mm).

Male genitalia. Unknown.

Variation. Some variation noted in the distinctness of the elytral pattern that is less distinct in the Eungella specimen than in the Mt Macartney specimen.

COLLECTING CIRCUMSTANCES. The label of one specimen reads 'RF (= rainforest) Intercept and pitfalls', which probably means that the specimen was sampled from the ground in the pitfall trap. Both recorded specimens were collected at 900m elevation in montane rainforest.

DISTRIBUTION. (Fig. 11) Eungella area and adjacent mountains west of Mackay, mid-eastern Queensland.

RELATIONSHIPS. Based on the coarse sculpture of the head and pronotum and the distinct microreticulation of the elytra, closely related to the group of species including *H. crassiceps*, *H. laticeps* sp. nov., and *H. parviceps* sp. nov.

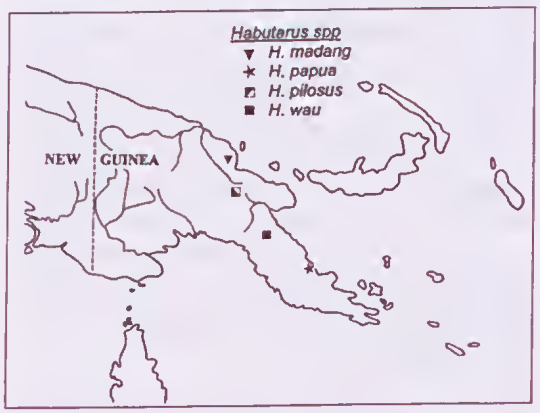

FIG. 9. Distribution of *Habutarus* species in New Guinea: *H. madang* sp. nov., *H. papua* (Darlington), *H. pilosus* (Baehr) and *H. wau* sp. nov.

Setitarus subgen. nov.

TYPE SPECIES. *Nototarus pilosus* Baehr, 1996, by present designation.

DIAGNOSIS. Subgenus of *Habutarus*, characterised by body surface absolutely glabrous without any trace of microreticulation, but covered by sparse, erect pilosity; head with small but unusually protruding eyes; male genital ring oval-shaped, aedeagus as in *papua*-group of subgenus *Habutarus* s. str., but slightly more compact.

Habutarus pilosus (Baehr, 1996) comb. nov.
(FIGS 6E, 7D, 9)

Nototarus pilosus Baehr, 1996: 608; Lorenz 1998: 471.

MATERIAL. HOLOTYPE: ♂, Papua NIle Guinée W. G. Ullrich / 24 IX 79 PNG/EHProv. Kainantu Onerunka / HOLOTYPE *Nototarus pilosus*, sp. nov. det M. Baehr 1995 (MCSN).

DIAGNOSIS. As for subgenus. Easily identified by the erect pilosity of the body surface.

PARTIAL REDESCRIPTION. *Measurements.* (Table 1) Length: 6.8mm; width: 2.8mm. Ratios. Length eye/orbit: 1.60; width/length of pronotum: 1.22; width widest diameter/base of pronotum: 1.36; width pronotum/head: 1.21; length/width of elytra: 1.36; width elytra/pronotum: 1.42.

Colour and body shape. See fig. 6E.

Male genitalia. (Fig. 7D) Rather large in comparison to body size. Genital ring wide, markedly convex, almost symmetric. Base deep. Aedeagus comparatively stout, slightly asymmetric, orifice short, situated on left side. Lower surface slightly concave, apex moderately elongate but rather stout, straight, very slightly widened at tip. Parameres very dissimilar, asetose, left one large, elongate, rather triangular, right one small, moderately elongate.

Female genitalia. Unknown.

Variation. Unknown.

COLLECTING CIRCUMSTANCES. Unknown.

DISTRIBUTION. (Fig. 9) Eastern Papua New Guinea. Known only from the type locality.

RELATIONSHIPS. Unique within the genus and sister species to all other species of *Habutarus*.

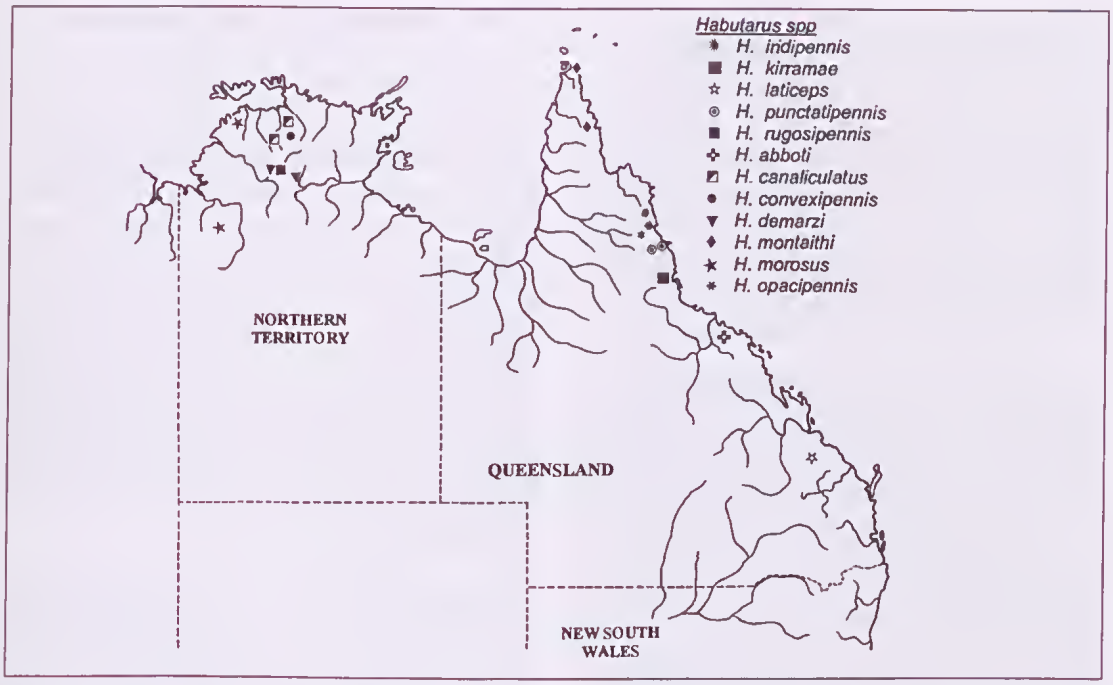

FIG. 10. Distribution of *Habutarus* species in northern Australia: *H. iridipennis* sp. nov., *H. kirramae* sp. nov, *H. laticeps* sp. nov., *H. punctatipennis* sp. nov., *H. rugosipennis* sp. nov., *H. abboti* sp. nov., *H. canaliculatuis* sp. nov., *H. convexipennis* sp. nov., *H. demarzi* sp. nov., *H. monteithi* sp. nov., *H. morosus* (Sloane) and *H. opacipennis* sp. nov.

DISCUSSION

Apart from the aberrant New Guinean *H. pilosus* (Bachr) all recorded species of *Habutarus* are quite similar in external as well as in genitalic morphology. Based on minor differences in body size and shape, and in the structure of their male aedeagi, two species-groups can be differentiated within the nominate subgenus. The *papua*-group contains generally smaller species bearing a less thickly sclerotised aedeagus that always has the apex straight and not hooked. These species occur in northern and eastern Australia and New Guinea. The *crassiceps*-group includes larger species bearing a thickly sclerotised aedeagus with distinctly hook-shaped apex. This group occurs only in eastern Queensland.

The structure of the male and female genitalia in *Habutarus* is very similar to that of the African-Oriental genus *Cymindoidea* Castelnau, though the two genera have rather different body shapes and structure of the body surface. Moreover all species of *Habutarus* are flightless and thus bear a shortened metathorax. Certainly the presence of the elongate filum within the male aedeagus is evidence of a close relationship

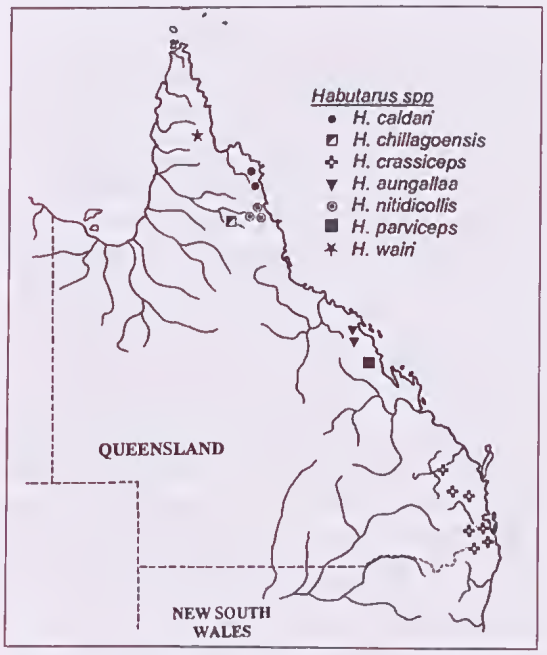

FIG. 11. Distribution of *Habutarus* species in Queensland: *H. calderi* sp. nov., *H. chillagoensis* sp. nov., *H. crassiceps* (Macleay), *H. eungellae* sp. nov., *H. nitidicollis* sp. nov., *H. parviceps* sp. nov. and *H. weiri* sp. nov.

of *Habutarus* and *Cymindoidea* and renders derivation of *Habutarus* from a *Cymindoidea*-like ancestor highly probable. Atrophy of wings and the restricted, marginal range of the genus *Habutarus* in eastern New Guinea and northern and eastern Australia suggest a recently achieved distribution and further corroborate its apotypic status as compared with the Oriental *Cymindoidea*. Hence, the origin of the *Habutarus*-lineage from a *Cymindoidea*-like stock is highly probable, making *Habutarus* an Oriental faunal element within the fauna of the Australian Region.

The distribution in tropical northern and eastern Australia in combination with a preference for rainforest further points to a post-Miocene immigration of the genus into Australia, after the Australian plate had contacted the south Asian insular belt. Thus, *Habutarus* seems to represent a young Oriental faunal element that developed a multitude of species in the eastern rainforests and reached as far south as the subtropical rainforests along the Queensland/New South Wales border. Its greatest species diversity, however, is in northeastern Queensland, where a number of species occur on separate mountain tops and tablelands being endemic to highly restricted ranges.

Many Australian species of the *papua*-group are very similar in shape and structure to the New Guinean species, and probably represent the original stock of immigrants into Australia. Although the members of the *papua*-group are still quite similar in appearance, a number of species that exclusively occur in the northern-most Northern Territory deviate by either possessing canaliculated and at the same time conspicuously opaque elytra bearing somewhat tectiform intervals (e.g. *H. morosus, H. demarzi, H. canaliculatus*), or very rugose elytra and, at the same time a conspicuously glabrous head and pronotum (*H. rugosipennis*). All species of the *papua*-group occurring in Queensland, on the other hand, possess more-or-less highly sericeous elytra, whereas the three species occurring in New Guinea do not and, in the structure of their elytra (moderately convex intervals, no distinct sericeous lustre, indistinct or absent punctation of intervals, moderate microreticulation) they seem to possess the most plesiomorphic character states within the genus.

Most species of the *crassiceps*-group are considerably larger and are distinguished by the hook-shaped apex of their aedeagus, both apomorphic character states. In the structure of their elytra, a number of species are rather similar to the New Guinean species, but two are distinguished by either the red colour of their elytra with a hint of a variegated pattern (*H. eungellae*), or by the light colour and extremely sericeous lustre of their elytra In Australia, species of the *papua*-group are not recorded from further south than the Kirrama Range southeast of Tully, and thus, they seem to be restricted to the tropics of north-eastern and northern Australia from slightly south of the Atherton Tableland to near the Northern Territory/Western Australia border. Species of the *crassiceps*-group occur along the whole of eastern Queensland, from Mt Finnigan, south of Cooktown, in the north, to the Queensland/New South Wales border, in the south. It is only this group, therefore, that was able to colonise subtropical regions, but apparently it does not occur further north in Cape York Peninsula as do some species of the *papua*-group.

It seems, then, that the Australian species of *Habutarus* are generally more apomorphic in a number of character states than the New Guinean ones, and this demonstrates the direction in which the first stock(s) of this genus immigrated into Australia: probably from eastern New Guinea through Cape York Peninsula to south-eastern Queensland on the one hand, and to far Northern Territory, on the other.

The high level of similarity of most species in external as well as in genitalic morphology suggests rather recent speciation events that may have been connected with the oscillating climatic and floristic changes in much of eastern and northern Australia during the Pleistocene, in the same way as postulated for other groups of flightless ground beetles in the same area that are rich in endemic species with very restricted ranges (see Darlington, 1961a-d; 1971; Baehr, 1995; 2003; 2005a; Yeates, et al. 2002). With respect to the Wet Tropics of northern Queensland, which are renowned for the high diversity of species with southern relationships ('bassian' faunal elements – for examples see references above), *Habutarus* is the first recorded carabid beetle group of Oriental origin that has managed to achieve comparable high levels of diversification. Almost all other rain forest dwelling carabid beetle genera of Oriental origin in northern Queensland are represented by single or a few species only and most of these inhabit lowland rain forest. In *Habutarus* it was probably the colonisation of mountain tops and subsequent atrophy of the wings that was responsible for the unusual diversity.

CHECKLIST AND KNOWN DISTRIBUTION OF *HABITARUS* SPECIES

Genus *Habutarus* Ball & Hilehie s. str.

papua (Darlington) . . . . . PNG
wau sp. nov.. . . . . PNG
madang sp. nov.. . . . . PNG
morosus (Sloane) . . . . . northern NT
demarzi sp. nov. . . . . northern NT
canalieulatus sp. nov. . . . . northern NT
rugosipennis sp. nov.. . . . . northern.NT
opaeipennis sp. nov. . . . . .north-eastern QLD
monteithi sp. nov. . . . . .north-eastern QLD
punctatipennis sp. nov. . . . .north-eastern QLD
ehillagoensis sp. nov. . . . . northern QLD
weiri sp. nov.. . . . . .north-eastern QLD
ealderi sp. nov. . . . . .north-eastern QLD
kirramae sp. nov.. . . . . .north-eastern QLD
eonvexipennis sp. nov. . . . . northern NT
erassiceps (Macleay). . . . . .south-eastern QLD
latieeps sp. nov.. . . . . eentral-eastern QLD
parviceps sp. nov. . . . . eentral-eastern QLD
abboti sp. nov.. . . . . .north-eastern QLD
nitidicollis sp. nov. . . . . .north-eastern QLD
iridipennis sp. nov. . . . . .north-eastern QLD
eungellae sp. nov. . . . . central-eastern QLD

Subgenus *Setitarus* subgen. nov.

pilosus (Baehr) . . . . . PNG

ACKNOWLEDGEMENTS

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LOWER CRETACEOUS CHIMAEROIDS (CHONDRICHTHYES: HOLOCEPHALI) FROM THE GREAT ARTESIAN BASIN, AUSTRALIA

ALAN BARTHOLOMAI

Bartholomai, A. 2008 04 30: Lower Cretaceous Chimaeroids (Chondrichthyes: Holocephali) from the Great Artesian Basin, Australia. *Memoirs of the Queensland Museum* 52(2): 49–56. Brisbane. ISSN 0079-8835.

Recently collected chimaeroid specimens from Lower Cretaceous (Albian) marine sediments of the Great Artesian Basin in Queensland, Australia, have enabled the taxonomy of these relatively rare fishes in these deposits to be clarified. Two Lower Cretaceous taxa were described from Australia in recent times, viz. *Edaphodon eyrensis* Long, 1985, and *Ptyktoptychion tayyo* Lees, 1986. A new species, *P. wadeae*, is here described from palatine, vomerine and mandibular tooth plates and is shown to differ significantly from the existing taxa. The holotype of the type species, *P. tayyo*, considered to be a mandibular tooth plate at the time of its description is identified as a palatine tooth plate. Mandibular tooth plates among the recently collected specimens are referred to this species and described. ❐ *Holocephali, Chimaeroidei, Chimaeridae, Callorhynchidae, Lower Cretaceous, Albian, Queensland, Great Artesian Basin, Toolebuc Formation, Allaru Formation, Edaphodon eyrensis, Ptyktoptychion wadeae sp. nov., Ptyktoptychion tayyo.*

Alan Bartholomai, Director Emeritus, Queensland Museum, PO Box 3300, South Brisbane, Queensland 4101; 30 June 2007.

Fossilised remains of chimaeroids (Holocephali) are uncommon among the Lower Cretaceous fish faunas of Australia and only two occurrences of this age have been recorded in the past. Both described taxa are from sediments deposited during the Aptian and Albian marine transgressions within the Great Artesian Basin, a structure that exists over much of inland Queensland and parts of other Australian states.

The first taxon was based upon an isolated, weathered mandibular tooth plate from the Aptian Bulldog Shale at Lake Phibbs, South Australia and was described by Long (1985) as the chimaerid, *Edaphodon eyrensis*. The second was also based on an isolated occurrence that was considered to be a mandibular tooth plate. This was recovered from the Albian Toolebuc Formation from near Boulia, western Queensland. Lees (1986) described this taxon as the callorhynchid, *Ptyktoptychion tayyo*.

Additional material that became available to Lees after her published work in 1986 was prepared by her but remained undescribed in the Queensland Museum collections. These specimens also came from the Boulia area, from the Toolebuc Formation at Spring Creek on "Canary" Station. Chimaeroid specimens collected by Dr Mary Wade from the Toolebuc Formation at "Borce Park" Station, west of Richmond in central Queensland were found unprepared in her private collection after her recent death. These, together with a calcilutite concretion containing a chimaeroid palatine tooth plate from the Albian Allaru Formation at "Currane" Station, north of Dartmouth in central Queensland, were transferred and incorporated into the collections of the Queensland Museum. An isolated vomerine tooth plate from "Canary" Station was collected recently by Mr Tom Hurley and was generously made available to the author.

All of the previously undescribed specimens form the basis for the present study. The terminology applied to the tooth plates largely follows that outlined in Stahl (1999). Similarly, the classification adopted herein is that outlined in that review of work on the group. Didier (1995) notes that tooth plates represent one of the few holocephalan mineralised tissues and that most fossil representatives are known only from such elements. She states that potential problems exist with some tooth plate characters. A developmental continuity is apparent between the two types of hypermineralised tissue recognised, viz. rods and pads. It is suggested this may have systematic importance because factors such as the effect of wear on the surface pattern of such tissues is not able to be assessed. The present work continues to apply the traditional use of the nature of the surface distribution of hypermineralised tissue – tritors.

Preparation of the material has been by a combination of mechanical techniques and chemical treatment involving dilute acetic acid.

All specimens are lodged with the Queensland Museum, bearing QMF numbers.

ABBREVIATIONS. abs = aboral surface; ait = anterior inner tritor; aot = anterior outer tritor; lbm = labial margin; lgm = lingual margin; lht = laminated hypermineralised tissue; mt = median or middle tritor; os = oral surfaee; pit = posterior inner tritor; pot = posterior outer tritor; sm = symphyseal margin.

SYSTEMATIC PALAEONTOLOGY

Class CHONDRICHTHYES
Superorder HOLOCEPHALI
Order CHIMAERIFORMES
Suborder CHIMAEROIDEI Patterson, 1965
Family CALLORHYNCHIDAE Garman, 1901
Subfamily CALLINORHYNCHINAE Stahl, 1999

Genus **Ptyktoptychion** Lees, 1986

TYPE SPECIES. *Ptyktoptychion tayyo* Lees, 1986, from the Toolebuc Formation of Lower Cretaceous (Albian) age.

REVISED GENERIC DIAGNOSIS. Tooth plates large to very large, thickened and robust, with deseending lamina present, often prominent. Vomerine tooth plate with eupped oral surface and with sharp, dentate mesial and labial margins. Tritoral matcrial over most of finely ridged anterior oral surface. Ridges low, numerous, subparallel, from deepest part of eupped surface to mesial and labial margins. Outermost ridge with tritoral material only along labial edge. Oral surfaces of both palatine and mandibular tooth plates deeply corrugated with ridges and grooves that subparallel the relatively deep symphyseal borders, except labiodistally in the palatine tooth plate which broadens the occlusal surface. Labial margin moderately to deeply indented, particularly in mandibular tooth plate. Tritors reduced, with middle tritor insignificant and with posterior inner tritor small to moderately large and vertical in palatine tooth plate and almost non-existent when present at all in the mandibular. Beak tritor with laminated tritoral tissue at base of labial surfaee mesially. Anterior inner tritor absent in mandibular tooth plate but present as vertical plate on outer side of innermost ridge in palatine tooth plate. Anterior outer tritor similarly developed but smaller and lower on middle ridge of palatine tooth plate and on the outer face of the middle ridge of the mandibular tooth plate. The posterior outer tritor reduced to series of knobs along labiodistal margin of palatine tooth plate and lining elongate trough and sides of groove inside labial margin. Aboral mandibular tooth plate surface gently convex but with broad, shallow groove parallel to and near labiodistal margin; palatine tooth plate with deep groove aborally, close to short, deep symphyseal surface. Labiodistal part of aboral surfaee angled orally from outer edge of this groove.

DISCUSSION

The presenee of large holocephalians in what has been considered by most workers to be sediments deposited under shallow-water marine conditions is somewhat perplexing. Stahl (1999) indicates that, with the exception of the possibly freshwater form, *Helodus simplex* Agassiz, holocephalians were and are marine animals that generally inhabit deep waters, although one taxon (*Hydrolagus* Gill) currently comes into shallower waters and *Callorhynchus* Lacépede itself breeds near shore. It is generally assumed that members of the group were slow swimming, bottom cruising and predominantly bottom feeding. Mesozoic species were often large and most exceeded a meter in length. From the size of the tooth plates in the species of *Ptyktoptychion* (and of *Edaphodon*) located in the Great Artesian Basin, size was certainly of this magnitude.

Food of members of the group is thought to have been mostly of bivalves and other molluscs, crustaceans and worms but larger forms could have included fish in their diets. Reduction in the surface expression of tritoral material, the form of the vomerine tooth plate and the dentate labial margins suggests that soft tissues were a major food preference. If present in sufficient numbers, large holocephalians could have been drawn to the abundant food sources present in the Cretaceous inland sea during the deposition of the Toolebuc Formation in Albian times. However, there is an abundance of detrital shell material in this Formation and little evidence of dominant, other bottom feeders that might have been associated with this aspect of the sediments. Physical reduction of hard, invertebrate skeletons undoubtedly occurred.

Recorded holocephalian tooth plates are robust and thus likely to have been readily fossilised. Their relative rarity suggests that numbers of individuals were most likely low. Absence to date of small individuals might also suggest that species recorded were not from populations breeding in the Basin but represented visitors from benthic

environments beyond the continent. However, all material recovered to date is from localities remote from the major oceanic link for the Basin, across the Euroka Shelf, immediately below what is now the Gulf of Carpentaria, a major journey for slow moving animals. It is considered most likely that the recorded taxa were indeed endemic and evolved especially to meet the conditions present in waters that were shallower than now suit most members of the group. Sharks and teleost predators of large size abounded in the Great Artesian Basin especially during the Albian, as did large to very large marine reptiles. These could have significantly culled numbers of smaller individuals of holocephalians if shallow-water breeding was occurring.

Ptyktoptychion tayyo Lees, 1986
(Figs 1–3)

Ptyktoptychion tayyo, Lees, 1986: 187.

MATERIAL EXAMINED. Holotype, QMF12987, nearly complete right palatine tooth plate, Toolebuc Formation of Lower Cretaceous (Albian) age from northeast paddock "Warra" Station, near Boulia, CWQ. QMF17853, partial left palatine tooth plate, Toolebuc Formation, Spring Creek, corner paddock, "Canary" Station, south-east of Boulia, CWQ; QMF17026, partial right mandibular tooth plate, Toolebuc Formation, corner paddock, Spring Creek, "Canary" Station, south-east of Boulia, CWQ: QMF17076, partial left mandibular tooth plate, Toolebuc Formation, corner paddock, Spring Creek, "Canary" Station, south-east of Boulia, CWQ.

AGE AND FORMATION. From the marine Toolebuc Formation of Lower Cretaceous (Albian) age.

REVISED DIAGNOSIS. Moderate sized. Length of palatine symphyseal margin in holotype is 53mm (but is 98mm in QMF17853), while width is 38mm, giving a minimal L: W ratio of 2.6. The length of the mandibular tooth plate is 110mm while the width is 35mm, yielding a L: W ratio of 3.1. Labial margins deeply dentate especially in mandibular tooth plate. Oral surface of palatine tooth plate with three ridges. Middle ridge about three-quarters as strongly developed as the innermost ridge. Grooves between all ridges deep. Four tritors present. Mandibular tooth plate with three tritors. Four ridges on oral surface at labial margin with inner three only progressively slightly weaker from innermost outwards and with three well defined grooves present.

DESCRIPTION. Known only from isolated palatine and mandibular plates.

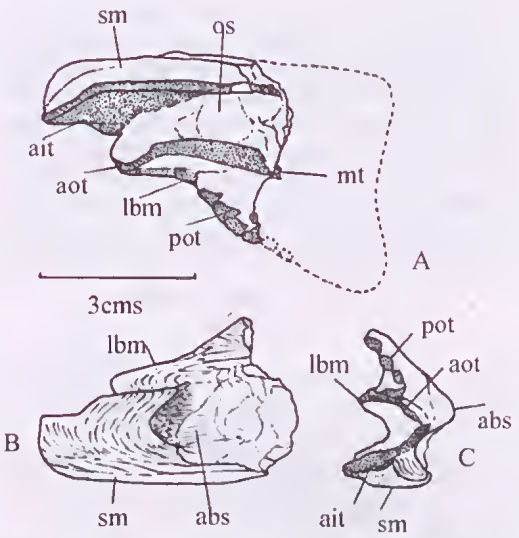

FIG. 1. *Ptyktoptychion tayyo* Lees, 1986, Holotype, QMF12987, partial right palatine tooth plate, see also Lees (1986) and Stahl (1999) for other illustrations; A, oral view (partially reconstructed); B, aboral view; C, mesial view; Scale = 3cms.

Holotype palatine tooth plate incomplete, lacking much of lingual and labiodistal margins but augmented by referred material. Tooth plate moderately robust, elongated triangular in shape. Length is ca. 98mm and width is ca.38mm (L: W ratio of 2.6). The symphyseal surface is short, deep, mesially triangular. Oral surface deeply corrugated with ridges and grooves. Innermost and middle ridges parallel symphyseal surface with middle ridge about three-quarters as high as the innermost ridge. Labial ridge low, set outwards at an angle of about 45° to the middle ridge. Mesially, end of inner ridge truncated and angled towards symphyseal surface. Labial surface of inner ridge with near vertical anterior inner tritor, extending sinuously along crest of ridge, sub-parallel to but not crossing deep groove curving down to indentation at labial margin. Anterior of crest angled sharply to labial margin. Labial surface of middle ridge with somewhat smaller, near vertical anterior outer tritor descending sharply anteriorly from crest to labial margin. Small knob of tritoral tissue present at margin on labial end of groove apparently associated with anterior outer tritor. Base of tritor curves into and sub-parallels deep groove between middle and labial ridges. At crest, tritor is turned outwards to broaden

surface, especially posteriorly. Posterior outer tritor present as series of three, low knobs along crest of low labial ridge, set outwards at an angle of ca. 45° to the labial face of the middle tritor. Labiodistal part of labial margin also angled orally at angle of ca. 45° to aboral base below inner ridge. Small posterior inner tritor present at crest of inner ridge. Aboral surface with deep, broad groove parallel to symphyseal margin, shallower mesially where roofed by strong

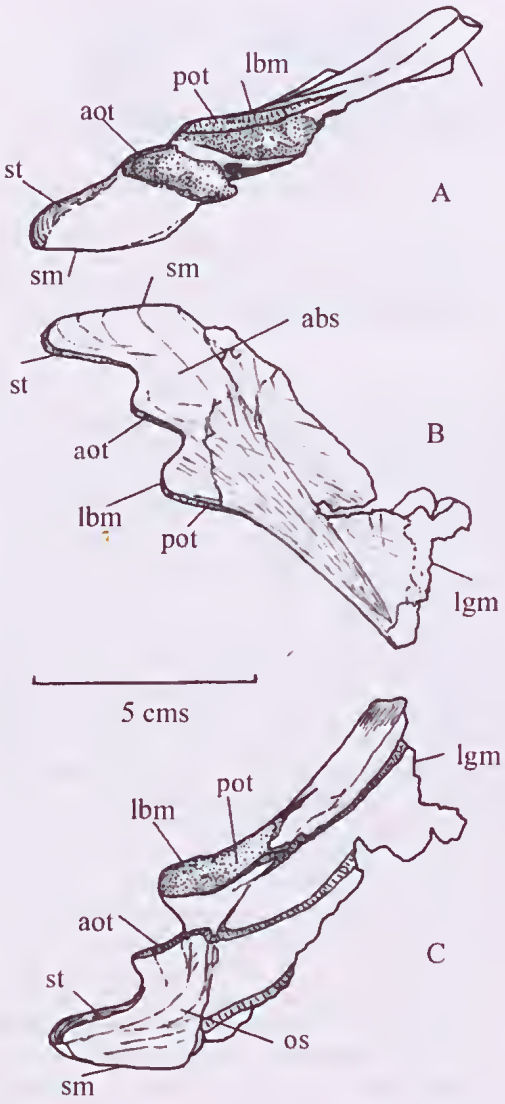

FIG. 2. *Ptyktoptychion tayyo* Lees, 1986, QMF17026, partial right mandibular tooth plate; A, labial view. B, aboral view; C, oral view; Scale = 5cms.

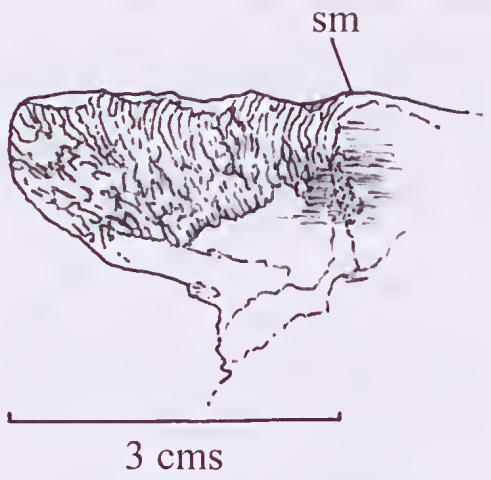

FIG. 3. *Ptyktoptychion tayyo* Lees, 1986, QMF17076, partial left mandibular tooth plate showing laminated tritoral tissue base exposed by weathering, oral view; Scale = 3cms.

descending lamina. Surface curves abruptly labially at angle of ca. 45° to base.

Mandibular tooth plate incompletely known. Tooth plate moderately robust, elongated and rhomboidal in shape. Length is 110mm and width is 35mm (L: W ratio of 3.1). Symphyseal surface is short, relatively deep, mesially triangular, bearing several longitudinal grooves parallel to aboral margin and slightly extended orally along oral margin. Oral surface deeply corrugated with ridges and grooves. Middle ridge apparently broadest and stoutest lingually, with mesial end dividing with inner part curving to above symphyseal margin contributing to crest of short, stout "beak". Outer and central parts form crests descending abruptly to dentate labial margin. These only slightly progressively lower than "beak". Outer ridge elongate but low and rounded, extending forwards along labiodistal part of labial margin to outermost dentate part. Major grooves along dentate part of labial margin deep, descending abruptly. Beak tritor present from mesial end, along dentate outer base of "beak" and across end of inner labial groove, composed of laminated hypermineralised tritoral tissue, grading internally into tritoral pad within "beak". Anterior inner, posterior inner and middle tritors absent. Anterior outer tritor near-vertical, forming outer face and crest of second dentate ridge. Posterior outer tritor elongate forming outer face and crest of third dentate ridge, lining shallow outer groove and forming part of

slightly raised labial margin. Descending lamina reasonably well-defined on aboral surface.

DISCUSSION

Lees (1986) concluded that, although the holotype of *Ptyktoptychion tayyo*, QMF12987, had a basically triangular outline typical of palatine tooth plates, its tritoral pattern indicated it represented a mandibular tooth plate. This situation was referred to in Stahl (1999) but was not remedied. It is clear that, with the larger samples now available, the specimen is a palatine tooth plate. The mandibular tooth plates described in the present study, although not found associated with palatine tooth plate remains of the same individual, are from specimens collected in similar sediments close to the type locality and have a close occlusal fit to the holotype corrugations, suggesting they are correctly referred to the same taxon.

A number of callorhynchids have palatine tooth plates that are subtriangular in outline and that have their posterior outer tritors subdivided into a number of "serial parts". None appears to have the deeply corrugated oral surface present in *P. tayyo*. The posterior inner and middle tritors in *P. tayyo* are generally less well-developed than in most of the other callorhynchids but are, regardless, present in the Queensland species as near-vertical walls of hypermineralised tritoral tissue in keeping with the anterior inner and outer tritors on the external faces of the ridges that descend to the labial margin. The dentate nature of the labial margin is also at variance with other recorded callorhynchine taxa. The genus *Ischyodus* Egerton has been recorded from Tertiary sediments in Australia (Stahl, 1999). If this palatine tooth plate occurrence represented *I. dolloi* Leriche as was suggested, some similarities exist with *P. tayyo*. The labial margin in the former is wavy, the shape is narrowly subtriangular and the posterior outer triton is represented by a series of small knobs. Mandibular tooth plates in *I. dolloi* have posterior and middle tritors that are much better developed, while the labial margin is less dentate. Both species have a laminated beak tritor. However, the deeply corrugated nature of the oral surface in *P. tayyo* is clearly distinctive. This feature alone serves to distinguish the Queensland species from the chimaerid, *Edaphodon eyrensis* Long, also from the Great Artesian Basin but from the slightly older Aptian sediments.

P. tayyo appears to have been the smallest of the known holocephalians living in the Lower Cretaceous inland sea of Australia. While its tooth plates were more graeile than those of the related species described herein, adult specimens may not have been greatly smaller in absolute size. Individuals probably exceeded a meter in length and were well equipped to cope with any of the small to medium sized, benthic organisms of the time and to have been capable of opportunistic feeding on midwater fishes and cephalopods.

Ptyktoptychion wadeae sp. nov.
(Figs 4–7)

MATERIAL EXAMINED. Holotype, QMF52601, almost complete right palatine plate lacking labiodistal and part of lingual margin and tip of beak, Toolebuc Formation of Lower Cretaceous (late Albian) age, from "Boree Park" Station, west of Richmond, NCQ. QMF52605, almost complete right vomerine tooth plate, "Canary" Station, south-east of Boulia, CWQ. QMF52603, almost complete right mandibular tooth plate, "Borec Park" Station, west of Richmond, NCQ. QMF52602, partial left mandibular tooth plate, "Boree Park" Station, west of Richmond, NCQ. QMF52604, partial left palatine tooth plate, Allaru Formation of Lower Cretaceous (late Albian) age, from "Currane" Station, north of Dartmouth, CWQ.

AGE AND FORMATION. From the marine Toolebuc and Allaru Formations of Lower Cretaceous (late Albian) age.

ETYMOLOGY. For the late Dr Mary Wade.

DIAGNOSIS. Tooth plates very large, very robust. Length of symphyseal margin in the holotype palatine plate is 101mm, while width of the oral surface across the back of the posterior outer tritor is 48mm, a L: W ratio of 2.1. (total length was presumably greater). The referred vomerine tooth plate has a symphyseal margin length of 74mm, while the width is 29mm. The mandibular tooth plate is 146mm long (ca. 156mm with the broken beak tritor restored) and 59mm wide at

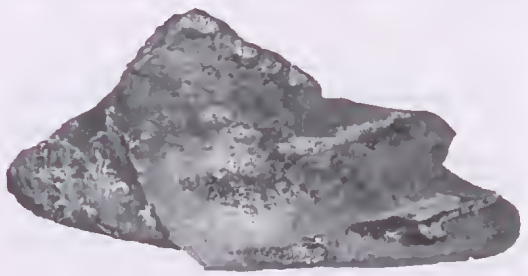

FIG. 4. *Ptyktoptychion wadeae* sp. nov., Holotype, QMF52601, partial right palatine tooth plate; Oral view; Scale = 5cms.

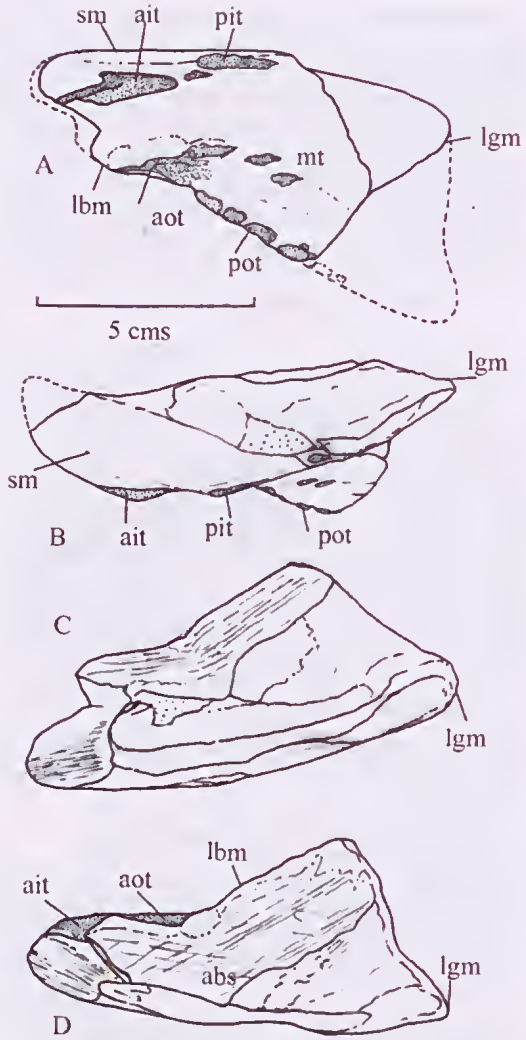

FIG. 5. *Ptyktoptychion wadeae* sp. nov., Holotype, QMF52601, partial right palatine tooth plate; A, oral view (partially reconstructed); B, symphyseal view; C, aboral view; D, labial view (oblique); Scale = 5cms. .

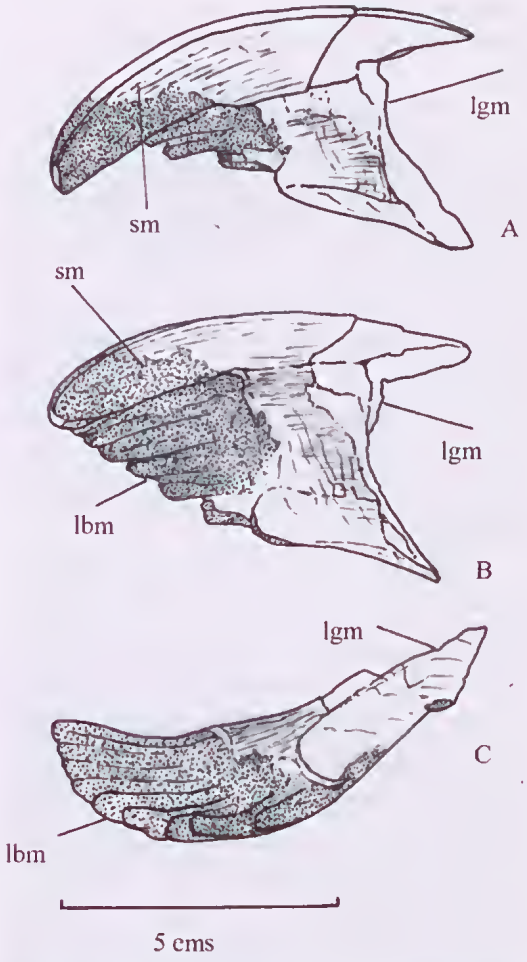

FIG. 6. *Ptyktoptychion wadeae* sp. nov., QMF52605, right vomerine tooth plate; A, symphyseal view; B, oral view; C, labial view; Scale = 5ems.

the back of the posterior outer tritor- a L: W ratio of 2.7. Labial margins dentate, especially in the mandibular tooth plate. Oral surface in palatine tooth plate corrugated, with three ridges diminishing significantly in strength from that parallel to the symphyseal margin to that along the labiodistal margin. Middle ridge less than half as well developed as the innermost ridge. Grooves between ridges broad, shallow. Five tritors present. Vomerine tooth plate relatively large, with oral surface deeply cupped, finely corrugated by nine ridges, across anterior tritor labially from mesial beak. Labial margin anteriorly finely dentate with sharpened cutting margin.

Mandibular tooth plate with five tritors. Oral surface corrugated with five ridges at or above labial margin. Lingually, oral surface ridges reduced to three, with middle ridge highest and strongest, radiating labiomesially into three. Labial margin moderately dentate, with three broad, low grooves separating ridges at margin. A descending lamina present on all tooth plates.

DESCRIPTION. Holotype palatine tooth plate incomplete but very large, robust, lacking tip of mesial margin and rear of tooth plate including labiodistal margin. Labial margin indented

anteriorly. Oral surface corrugated with three ridges decreasing in strength from that below the symphyseal margin outwards. The middle ridge is less than one-half as high as that below the symphyseal margin. The outer ridge is even less well developed than the middle ridge but is as high as the innermost ridge because of marked downwards flexure of the labial part of the tooth plate. Twisting of the tooth plate is accentuated by upwards and medial flexure of the back part of the inner ridge behind the symphysis. Both the posterior of the middle ridge and the labial ridge are angled outwards at about 30° to the front of the middle ridge. The grooves between the ridges are broad and shallow. Five tritors are present. Anterior inner tritor largest on outer, near vertical side of inner ridge. Anterior outer tritor smaller, present on outer, near vertical surface of middle ridge. Posterior outer tritor low, produced into three knobs along strongly inclined labiodistal margin and also set at an angle of ca. 45° to the anterior outer tritor. Posterior inner tritor very small with even smaller knob of subdivision anteriorly. Anterior outer tritor moderately well developed on outer, near vertical surface of middle ridge, extending back from labial margin. Posterior outer tritor present as series of five small knobs of tritoral material along crest of outer ridge (six in QMF52605). Middle tritor very small, present as series of two knobs of tritoral tissue subparallel to posterior outer tritor (four in QMF52605). Aboral surface bearing a deep, broad, longitudinal groove outside symphysis, probably capped anteriorly. Descending lamina prominent.

Vomerine tooth plate relatively large, with oral surface shaped like a cupped hand. Symphyseal margin crescent-shaped in symphyseal view, deep towards middle of tooth plate. Mesial and labial margins relatively sharp, dentate. Tritoral material present over most of front of oral surface as subparallel, low ridges running from deepest part of cupped surface and slightly behind this to mesial and labial margins. Hypermineralised tritoral tissue present as laminated overlapping plates, especially along oral surfaces of ridges within cupped surface, together with a mixture of minute, bead-like surface dots and tritoral pads. Beak slightly hooked. Ridges shorten and broaden towards outer part of labial margin, while outermost ridge with tritoral material only at labial edge, continuing along deep edge of margin. Aboral surface strongly convex longitudinally and transversely with descending lamina present but weak. Lingual margin open.

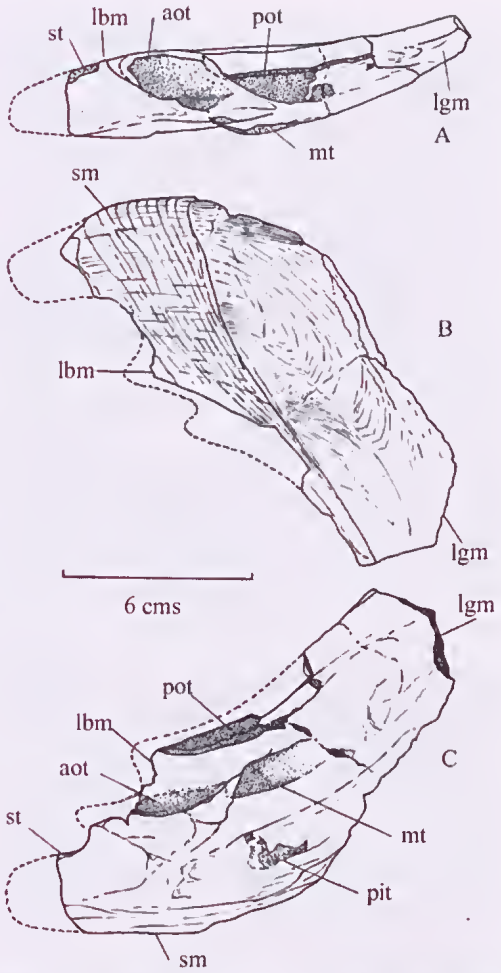

FIG. 7. *Ptyktoptychion wadeae* sp. nov., QMF52603, partial right mandibular tooth plate, all partially reconstructed; Scale = 6cms; A, labial view; B, aboral view; C, oral view.

Mandibular tooth plate large, robust, with sublunate oral surface and dentate oral margin. Aboral surface gently convex longitudinally and more strongly so transversely, sometimes with very shallow, broad, longitudinal depression towards outer oral margin. Symphyseal margin deep, with irregular, longitudinal ridges and grooves, gently convex aborally and narrowing posteriorly. Symphyseal margin extends anteriorly along short, robust, symphyseal beak, subtriangular in section. Oral surface with very strong, broad, longitudinal ridge on mid-posterior moiety, dividing into three angular ridges anteriorly, one to back of symphyseal beak, and the others to delimit the angled edges of broad grooves that descend to the oral margin.

A broad, shallow groove runs longitudinally between the middle ridge and the upper rim of the symphyseal margin. A low rounded ridge at posterior of oral margin subparallel to symphyseal margin and is separated from middle ridge by narrow groove that broadens anteriorly. Up to five tritors present. Symphyseal tritor moderately large, developed towards base of beak along oral margin, with edges mostly of parallel, overlapping and inclined, semi-circular lamelli, grading inwards into pads. Posterior inner tritor usually not developed, middle tritor small and strap-like, anterior outer tritor restricted to inner wall of middle groove, while more extensive posterior outer tritor lines sides and base of oral end of outer groove, including forming much of posterior rim of oral margin. Aboral surface generally marked by very minor, longitudinal ridges, intersecting with one or two angled sets of slightly stronger, transverse ridges. Descending lamina moderately prominent.

DISCUSSION

It is possible that QMF52601, the holotype palatine tooth plate of *P. wadeae* sp. nov. and the referred mandibular tooth plates (QMF52603 and QMF52602) were all derived from the one individual. Unfortunately, full details of the collection of the material were not included with the specimens located in the effects of Dr. Wade following her death. For this reason, only the palatine tooth plate has been designated as the holotype to facilitate separation of *P. wadeae* from *P. tayyo* Lees. The vomerine tooth plate could have been associated with the latter taxon, coming as it did from a locality close to the type locality for that species. However, it is clearly more robust than would have been expected for *P. tayyo* and thus appears to be more reasonably referrable to *P. wadeae*.

The occurrence of *P. wadeae* in a calcilutite nodule from the Allaru Formation at "Currane" Station, north of Dartmouth, is of interest. The locality has produced a broad faunal assemblage of marine invertebrates that can only be interpreted as being of near-shore, shallow-water origin. Among these is a broad crustacean fauna reported upon by Woods (1953). Such animals would have provided an ideal food source for *P. wadeae* and their remains support the conclusion that the holocephalans of the Great Artesian Basin were unlike the bulk of their living relatives in frequenting shallow and even near littoral marine habitats.

ACKNOWLEDGEMENTS

Dr Alex Cook of the Queensland Museum is thanked for referring the material located in the effects of the late Dr Mary Wade to the author and for the transfer of the vomerine tooth plate from "Canary" Station. Mr Tom Hurley is especially thanked for his generosity in donating that specimen to the Queensland Museum. Thanks are also extended to Dr Susan Turner who made literature available and who discussed the taxonomic issues involved.

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AN EARLY DEVONIAN GASTROPOD FAUNULE FROM THE MT ETNA BEDS CENTRAL QUEENSLAND

ALEX G. COOK AND MATTHEW C. NG

Cook, A.G. & Ng, M.C. 2008 04 30: An early Devonian gastropod faunule from the Mt Etna beds central Queensland. *Memoirs of the Queensland Museum* **52**(2): 57–64. Brisbane. ISSN0079-8835.

Gastropods from the uppermost Mt Etna Limestone, central Queensland are represented by eleven taxa including the new taxon *Beuchelia sandsi* sp. nov. Most are imperfectly preserved and hence unidentifiable beyond genus, but do provide notable occurrence data of biostratigraphic importance. Lochkovian-Pragian-gastropod data remains poor for eastern Gondwanaland, but Old World realm affinities are apparent in this faunule. ❐ *Gastropods, Devonian, Pragian, Queensland.*

Alex G. Cook & Matthew C. Ng, Queensland Museum, PO Box 3300, South Brisbane Qld 4101 (email: alex.cook@qm.qld.gov.au); 1 November 2006.

Earliest Devonian (Lochkovian-Pragian) gastropods from Australia are poorly known with the exception of a Lochkovian faunule from the Windellama Limestone of NSW (Mawson, Smith & Talent, 2002); partial descriptions of an extensive (Lochkovian-Pragian) fauna from the Garra Limestone (Farrell, 1992) and the late Pragian Lilydale Limestone fauna (Tassell, 1976, 1980). This small faunule recovered from the uppermost Mt Etna Limestone, north of Rockhampton, Queensland represents a small but noteworthy insight into the gastropods of this age from east Gondwanaland.

Mt Etna Limestone has been variously referred to as Mt Etna Beds, Mount Holly Beds or Mt Alma Formation and represent an allocthonous block within the eastern Yarrol terrane. The limestone units contain an extensive coralline fauna, and less common brachiopods have been recovered near the top of the limestone sequence. In addition rare specimens of gastropod were recovered as part of this silicified fauna (QML 1353). Conodonts from the lowermost limestone indicate a Pragian (*sulcatus* CZ) age (Mawson & Talent, pers. comm.) but there is poor age control on the top of the sequence. On the eastern margins of Mt Etna, conformably on the carbonate succession, occurs a clastic unit containing abundant, if poorly preserved gastropods, bivalves and rarer nautiloids. This unit is exposed at Bench 10 within the Mt Etna Limestone mine designated QML1295.

Affinities of this fauna are difficult to gauge given the imperfect preservation. Emsian faunas from New South Wales contain *Coelocylcus*, ?*Coelozone*, *Oehlertia* and members of Gosseletininae (Tassell, 1982). *Ruedemannia (Batteniella)*, *Tremanotus*, from the Lochkovian to Pragian of New South Wales and Victoria (Tassell, 1976; Mawson, Talent & Smith, 2002). Such taxa are typical of old world realm faunas (Cook, 2000) but absence of data from China and other Asian Gondwanaland elements makes precise correlation impossible.

SYSTEMATIC PALAEONTOLOGY

Order AMPHIPGASTROPODA Simroth, 1906

Family BELLEROPHONTIDAE M'Coy, 1851

Subfamily BUCANIINAE Ulrich and Scofield, 1897

Tribe BUCANIIDES Ulrich and Scofield, 1897

Coelocyclus Perner, 1903

TYPE SPECIES. *Bellerophon* (*Coelocyclus*) *rarissimus* by original designation from the Devonian of Bohemia.

Coelocylcus sp.
(Fig. 1A–D)

MATERIAL. QMF37346–37350 from QML1295.

DESCRIPTION. Shell involute, small to medium, maximum width 13.5mm, maximum diameter 17.0mm, slowly expanding; widely doubly phaneromphalous with deep umbilicus, Whorl profile almost quadrate with sharp margin between umbilical zone and peripheral midwhorl; slit narrow and only slightly raised; growth lines

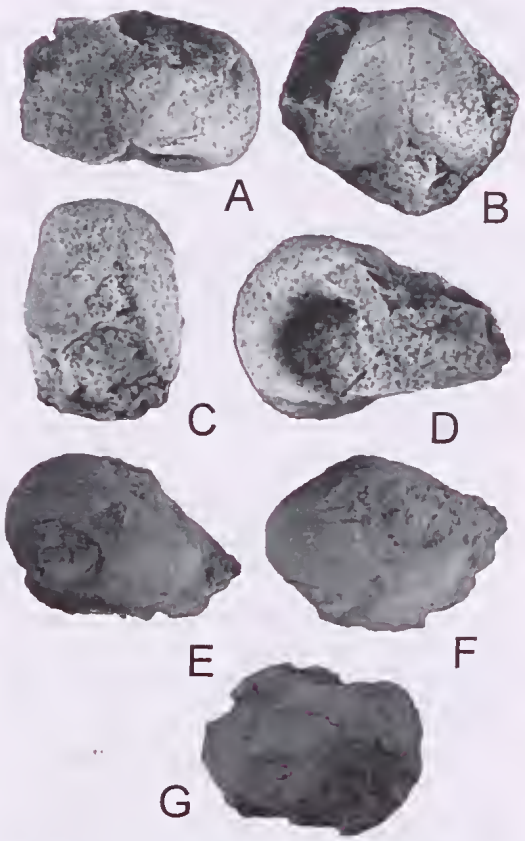

FIG. 1. A–D, *Coelocyclus* sp.; A, B. QMF37346 × 2.3; C, D, QMF37347 × 2.3; E–G, ?*Tremanotus* sp. QMF37342 × 0.6.

very fine and numerous deflected backwards evenly from the margin towards the slit.

REMARKS. The quadrate whorl profile and narrow slit undoubtedly allies the two specimens to *Coelocyclus* Perner. *Coelocyclus hadroni* Tassell, 1982 from the Emsian '*Receptaculites*' Limestone of New South Wales possesses coarser ornament.

The specimens lack the apertural flaring and reticulate ornament of *Bucania* Hall.

Tribe SALPINGOSTOMATIDES Koken, 1925

Tremanotus Koken, 1896

TYPE SPECIES. *Cyrtolites lamillifer* Lindstrom 1884 from the Silurian of Gotland by subsequent designation.

?**Tremanotus** sp.

(Fig. 1E–H)

MATERIAL. QMF 37342, QMF37343 from QML 1295.

DESCRIPTION. Shell large involute, doubly phaneromphalous but poorly preserved specimens; up to 34mm wide, 44mm diameter rapidly expanding and flared at apeture. Margin with trace of line of probable tremata.

REMARKS. Probable tremata suggest placement within the penecontemporaneous *Tremanotus*, well known from the Pragian Lilydale Limestone of Victoria (Tassell, 1976). Etheridge (1888) illustrated a specimen supposedly from the Early Triassic of the Sydney Basin, however the specimen is clearly *Tremanotus*, probably soureed from the Lilydale Limestone. We have been unable to locate the specimen within the Australian Museum eolleetion, and any formal reference to it has been thankfully ignored in the last 117 years.

Order ARCHAEOGASTROPODA Thiele, 1925
MORPHOGROUP 'TROCHOMORPHA'
Family SINUOPEIDAE Wenz, 1938
Subfamily TURBONELLININAE Knight, 1956

Leptozone Perner

TYPE SPECIES. *Pleurotomaria (Leptozone) esthetica* Perner by monotypy from the Lower Devonian Koneprusy Limestone, Prague Basin.

Leptozone sp.
(Fig. 2A–M)

MATERIAL. QMF37887–QMF37896, QMF42094 from QML1295.

DESCRIPTION. Shell medium sized, turbiniform, phaneromphalus up to 14.1mm wide and 14.5mm high with spiral angle of approximately 60°; suture weakly impressed more so on later whorls, located at mid whorl periphery; upper whorl gently rounded meeting suture at about 10° base rounded. Ornament consists of very fine, numerous spiral threads and very fine growth lines. Growth lines slightly prosocline on upper whorl face; defleeted at mid whorl forming a shallow sinus.

REMARKS. The shell shape, narrow midwhorl sinus and the fine spiral ornament places the material comfortably within *Leptozone*.

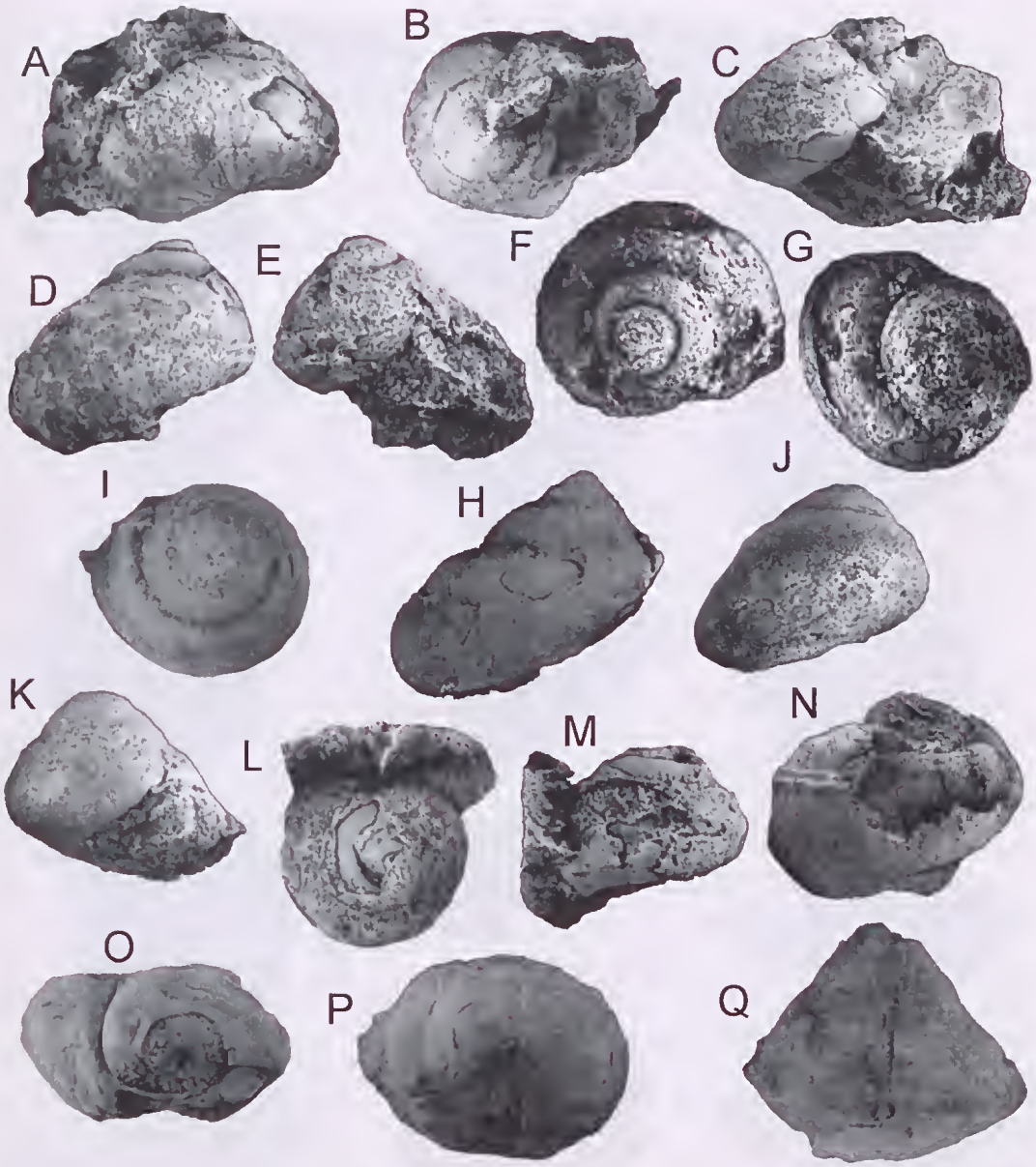

FIG. 2. A–M, *Leptozone* sp. A–C, QMF37895, × 2.5; D–F, QMF37896 ×3.2; G, H, QMF 37887, × 2; I–K, QMF37888 × 2.5; L,M, QMF42094 × 3.5; N,O. *Ceolozone* sp. QMF33805 × 1; P, Q, ?*Oehlertia* sp. QMF33804 × 1.

Family SINUOPEIDAE Wenz, 1938
Subfamily SINUOPEINAE Wenz, 1938

Indet. Sinuopeinae

MATERIAL. QMF48203 from QML1353.

DESCRIPTION. Shell small, low turbiniform, phaneromphalous, 6.2mm wide, 4.5mm high, spire angle approximately 130°; suture impressed; whorls embraee at periphery just below mid whorl; whorl profile rounded; ornament of eoarse eomarginal rugae which become slightly foliate at the mid whorl; rugae defleeted to wide, shallow sinus just below mid whorl.

REMARKS. The shell form and wide sinus indicate clear sinuopcid affinities. Sinus position indicates placement within Sinuopeinae, although no known

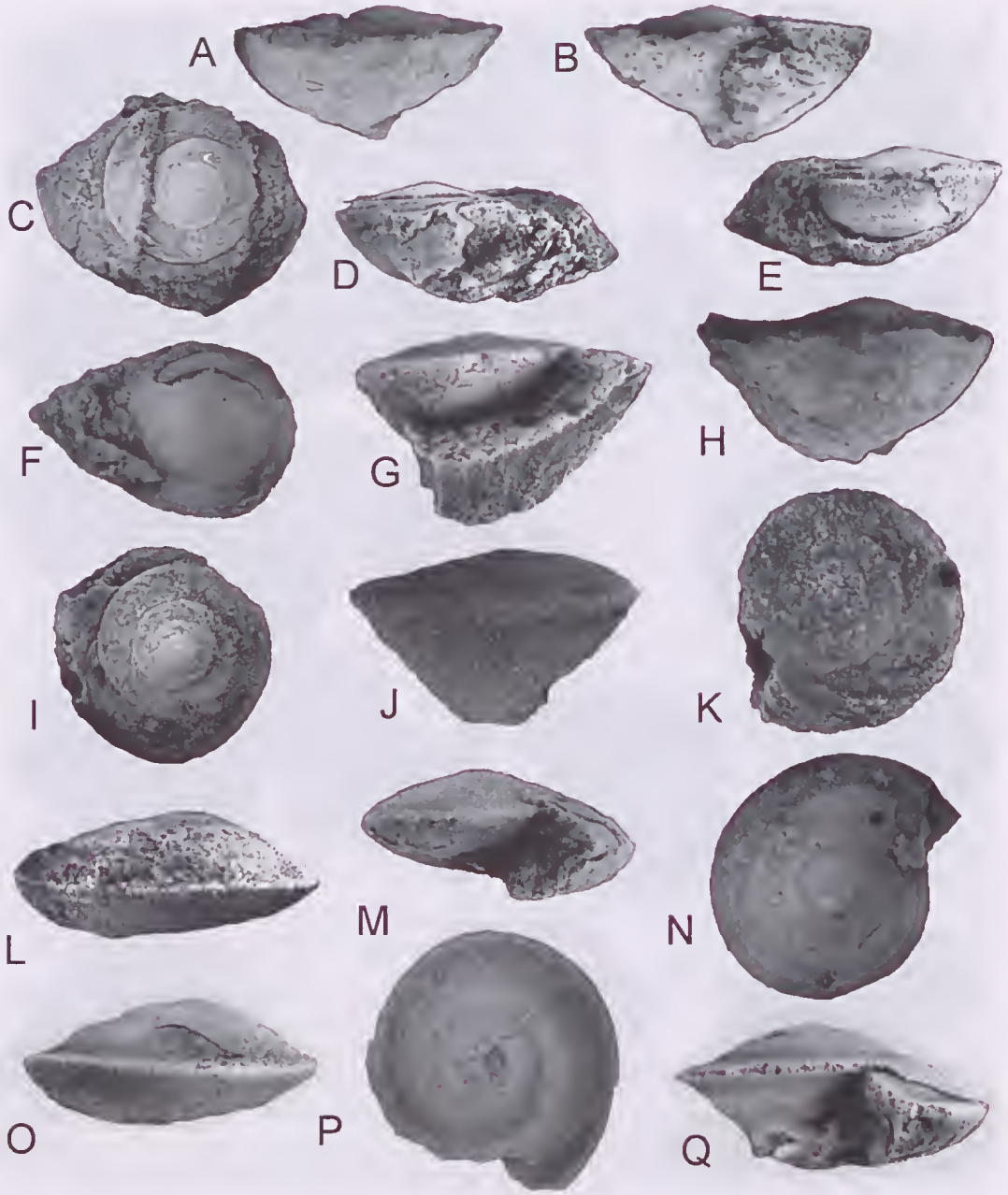

FIG. 3. A–K, *Beuchelia sandsi* sp. nov.; A–C, Holotype QMF37331 × 1.7 side, apertural and apical views; D–F, Paratype QMF37334 × 1.6, apertural side and apical views. G–I, Paratype QMF37333 × 1.4, oblique apertural, side and apical views; J, K, Paratype QMF37332, × 3.5, side and apical views; L–Q Liospirinae indet.; L–N, QMF 33716, × 1.6, side apertural and apical views; O–Q, QMF33717 × 2, side apical and apertural views.

taxa display sueh foliate ornament. Additional material would elueidate this unusual taxon.

MORPHOGROUP 'SELENIMORPHA'

Family RAPHISTOMATIDAE Koken, 1896

Subfamily LIOSPIRINAE Knight, 1956

Liospirinae indet.
(Fig. 3L–Q)

MATERIAL. QMF33716–8 from QML 1295.

DESCRIPTION. Shell small, narrowly phanerom-phalus, lentieular, up to 18mm wide 8mm high with a spiral angle of approximately 140°. Suture weakly impressed to flush, located at peripheral selenizone on angulated midwhorl. Periphery sharper in smaller specimens. Upper and lower whorl faces equally rounded; ornament very fine prosocline growth lines on upper surface, lower surface ornament unknown.

REMARKS. Narrow umbilicus and lenticular shell shape place the speeimen close to *Anygomphalus*, but the Mt Etna material lacks a circumumbilical cord. Lack of a gradate upper profile precludes assignment to *Arizonella* Stoyanow, and the material cannot be *Liospira* due to thc presenee of the umbilicus. Poor prescrvation prevents generic assignment.

Subfamily RAPHISTOMATINAE
Koken, 1896

Buechelia Schlüter, 1894

TYPE SPECIES. *Beuchelia goldfussi* from the Middle Devonian of Germany.

REMARKS. Heidelberger & Koch (2005) erected *Buechelia nodifera* from the Givetian 'Massenkalk', which is similar to *Buechelia nodosa* Blodgett, 1992 from the Eifelian of Alaska. We are uneonvinced that they represent separate taxa.

Buechelia sandsi sp. nov.
(Fig. 3A–K)

DIAGNOSIS. *Buechelia* with very low spired to flat upper surface, lacking nodes at periphery.

ETYMOLOGY. For Noel Sands, for his eontribution to the understanding of Mt Etna.

MATERIAL. Holotype, QMF37331. Paratypes QMF37332–40 all from QML1295.

DESCRIPTION. Shell medium sized, anom-phalous, inverted eonieal with narrow base and nearly flat upper surface which is weakly arehed, up to 22mm wide, and 14mm high. Sutures barely adpressed to flush, loeated at periphery. Periphery a sharp angulation bearing selenizone. Upper whorl faee with numerous fine eords which are strongly prosocline; Lower whorl face steep forming cone, without ornament.

REMARKS. Clear absence of lower faee ornament, flattened upper surface and the inverted wide conical shape place the material within the genus. It differs from the type speeies *B. goldfussi* Schlüter from the Givetian of Germany by having a lower profile on the upper surfaee. *B. nodosa* Blodgett (=*B. nodifera* Heidelberger & Koch) from the Eifelian of Alaska and Givetian of Germany possess peripheral nodes which are absent in the Mt Etna material.

Family EOTOMARIIDAE Wenz, 1938

Subfamily EOTOMARIINAE Wenz, 1938

Tribe PTYCHOMPHALIDES Wenz, 1938

Oehlertia Perner, 1907

?Oehlertia sp.
(Fig. 2P, Q)

MATERIAL. QMF33804 from QML1295.

DESCRIPTION. Shell conieal, trochiform, anom-phalus, up to 22mm high, 16mm wide with a spre angle of approximately 45°; suture weakly impressed to flush, loeated at lower part of periphery which bears a slit bordered by two low cords. Growth lines fine numerous, slightly prosocline from suture to periphery. Base gently rounded.

REMARKS. Poor detail of growth lines and the slit prevents accurate assessment, but the shell shape and wide peripheral selenizone suggest *Oehlertia* Perner 1907.

Family LOPHOSPIRIDAE Wenz, 1938

Indet. Lophospiridae aff. **Lophospira** sp.
(Fig. 4A–I)

MATERIAL. QMF33377, QMF33376, QMF33374, QMF33807, QMF33808, QMF33809, QMF33897, QMF33887 from QML1295.

DESCRIPTION. Shell high-turbiniform, anomphalus somewhat gradate, up to 27mm high, 19mm wide with a spiral angle of; whorl profile angular with upper whorl face consiting of prominent subsutural ramp flattening to a strong peripheral carina. Lower whorl face rounded with prominent cord below periphery. Suture impressed; whorls embrace below periphery at prominent cord; growth lines fine and numerous; sinus on carina. Aperture rounded but elongate with lower part of lip slightly tapered.

REMARKS. The material falls within a poorly understood complex of genera within the scleni-morphs of Lophospiridae, which trace out a complex Ordovician-Carboniferous history through *Lophospira*, *Ruedemannia*, *Worthenia* and their constituent subgenera. Frýda & Manda (1997) confirmed the validity of *Ruedemannia (Hanusispira)* Horný and erected *Ruedemannia (Batteniella)*, as taxa within this complex, but both subgenera have additional spiral ornament in comparison to the Mt Etna material. *Lophospira* Whitfield (Ordovician to Silurian) compares well with the Mt Etna material. Strong homeomorphy with *Lophospira*, a reduction in upper whorl face cords and disappearance of lower whorl face cords, not forming nodes (as in *Worthenia*), is a simple and highly likely variation within the group. It is possible that instead of secondary homeomorphy, the taxon represents a holdover of *Lophospira* itself.

Subfamily RUEDEMANNIINAE Knight, 1956

Ruedemannia Foerste, 1914

Ruedemannia (Battenella)
Frýda and Manda, 1997

?Ruedemmannia (Battenella) sp.

MATERIAL. QMF48205 from QML1353.

DESCRIPTION. Shell small, high turbiniform, up to 3.5mm high, 2.6mm wide; spire angle approximately 40°; suture impressed, whorls meet just below mid whorl; upper whorl face meets suture at approximately 20° from horizontal; midwhorl flattened with suggestion of selenizone. Weak traces of prominent spiral cords are only preserved ornament on these poorly preserved specimens.

REMARKS. The shell form and remnants of spiral cords suggest placement in *Ruedemannia (Batteniella)* but this is not certain given the poor preservation. The subgenus has been recorded in New South Wales (Mawson, Smith & Talent, 2002).

Family GOSSELETININAE Wenz, 1938

Subfamily COELOZONINAE Knight, 1956

Coelozone Perner, 1907

Coelozone sp.
(Fig. 2 N–O)

MATERIAL. QMF33805 from QML1295

DESCRIPTION. Shell turbiniform, 32mm wide, approximately 32mm high, apex missing; spire angle approximately 40°; suture impressed; whorls meet at upper margin of selenizone slightly above midwhorl. Shell thick Whorl profile strongly rounded; base rounded, anomphalous. Selenizone slightly above periphery just above midwhorl, wide and convex within two strong bordering spiral cords. Growth lines fine, numerous prosocline on upper whorl face, slightly prosocline below, deflected deeply into selenizone. Apex and protoconch unknown.

REMARKS. Width and location of the selenizone, the shell shape and places the specimen within the *Coelozone* Perner 1907. The specimen is slightly higher-spried than the type species *Pleurotomaria (Coelozone) verna*, but cannot be specifically assigned.

Order STYLOGASTROPODA
Frýda and Bandel, 1997

Family LOXONEMATIDAE Koken, 1889

Katoptychia Perner, 1907

TYPE SPECIES. *Katoptychia alba* Perner 1907, from the Lower Devonian of the Prague basin, by subsequent designation.

?Katoptychia sp.
(Fig. 4 J-M)

MATERIAL. QMF37344, QMF37345 from QML1295.

DESCRIPTION. Shell, medium sized, high spired approximately 18mm high, 5mm wide with spire angle of approximately 15°. Suture nearly flush, whorls embrace at periphery which is low on the flattened whorl face. Base anomphalous. Ornament lacking.

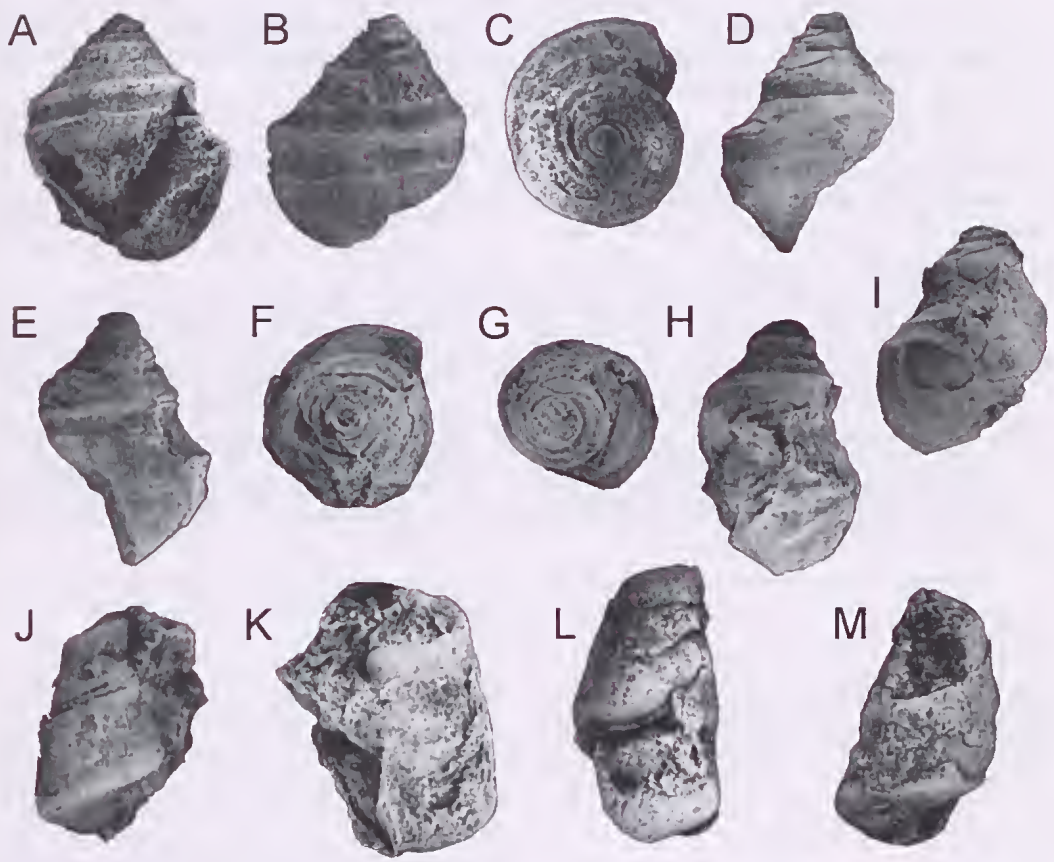

FIG. 4. A–l, Indet. Lophospiridae aff. *Lophospira* sp. A–C, QMF33373 × 1.6. D–F, QMF33803 × 1.3. G–I, QMF33375 × 1. J–M, *?Katoptychia* sp. J, K, QMF37344 × 2. QMF37345 × 2.

REMARKS. The characteristic whorl profile suggests the genus but lack of ornament prevents accurate assignment.

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REVISION OF THE AUSTRALIAN ANT SPIDER GENUS *HABRONESTES* L. KOCH 1872 (ARANEAE: ZODARIIDAE): III THE *HABRONESTES MACEDONENSIS* - GROUP IN QUEENSLAND AND NEW SOUTH WALES.

B. BAEHR

Baehr, B. 2008 04 30: Revision of the Australian ant spider genus *Habronestes* L. Koch 1872 (Araneae: Zodariidae): III. The *Habronestes macedonensis*-group in Queensland and New South Wales. *Memoirs of the Queensland Museum* **52**(2): 65–87. Brisbane. ISSN 0079-8835.

The Queensland and New South Wales species of the *maeedonensis*-group of the genus *Habronestes* L. Koch, 1872 are revised. The genus now contains 50 species Australia-wide, with 15 newly described and five previously known species of the *H. macedonensis*-group from Queensland and New South Wales. The species here described are *H. arehiei*, sp. nov. (♂), *H. boq*, sp. nov. (♀, ♂), *H. braemar*, sp. nov. (♂), *H. clansoni*, sp. nov. (♀, ♂), *H. diekmani*, sp. nov. (♂), *H. diocesegrafton*, sp. nov. (♂), *H. drummond*, sp. nov. (♀, ♂), *H. gallowayi*, sp. nov. (♂), *H. gayndah*, sp. nov. (♂), *H. gimbardo* sp. nov. (♂), *H. hooperi*, sp. nov. (♂), *H. jankae*, sp. nov. (♀, ♂), *H. powelli*, sp. nov. (♀, ♂), *H. tillmani*, sp. nov. (♂), *H. ulrichi*, sp. nov. (♂). The female of *H. migari* is described for the first time. A key is provided for all *H. maeedonensis*-group species known to date. ❐ *Arachnida, Araneae, Australia, Habronestes, new species, systematics, taxonomy.*

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The quite colourful ant spiders, Zodariidae, are one of the dominant families of ground hunting spiders in Australia. With 249 species currently described and an estimated total of 350-400 species, Australia has the richest known zodariid fauna worldwide (Jocqué, 1991, 1995a, b; Jocqué & Baehr, 1992, 1995, 2001; Baehr & Jocqué 2000, 2001; Baehr 2003a, b, c, 2004 a, b, 2005; Baehr & Churchill 2003; Jocque & Churchill 2005; Raven & Baehr 2000). The Australian zodariid fauna is most diverse in the tropical and subtropical regions but the family reaches as far south as Tasmania were only three genera are known, *Asteron* (Jocqué & Baehr, 2001), *Habronestes* and *Neostorena,* the latter of which is unrevised.

This paper is the third in a series revising the large, endemic Australian genus *Habronestes* (Baehr, 2003c; in press) and deals only with the fauna of Queensland and New South Wales. Species of *Habronestes* are yellow-spotted, medium sized (4.5 – 8.0 mm) spiders that are diurnal and feed predominantly on ants, mimicking their behaviour and sometimes even their chemical traits (Allan, Elgar & Capon, 1996).

This work is dedicated to the people and institutions who supported this work and continuing research on spider taxonomy, namely the Biodiversity Program of the Queensland Museum, the Australian Biological Resources Study (ABRS) and the Bank of Queensland and the Anglican Diocese of Grafton both of which contributed to the Queensland Museum Foundation 'Name a Spider' project.

MATERIAL AND METHODS

Descriptions were generated with the aid of Intkey (Dallwitz et al., 1998) and shortened where possible. Locality data were managed and maps created with Biolink version 1.5 (CSIRO Entomology, Canberra, Australia; http://www.biolink.csiro.au/). The distributional data presented in Fig. 10 relate only to newly examined specimens listed in this paper. For additional distributional records of the previously described species of *Habronestes* refer to Baehr (2003c; in press).

Drawings include the body, right palp and epigyne. All measurements are in millimetres. Scales of drawings are: body (1mm), palp (0.5mm), epigyne (0.1mm). Epigynes were cleared in lactic acid. Descriptions of spination and colour patterns follow those in Baehr (2003c). Female allotype species descriptions mention only the differences from the male. Throughout the text, figures cited from Baehr (2003c) are listed as 'fig.' those presented in this paper as 'Fig.'.

Character abbreviations. ALE, anterior lateral eyes; AME, anterior median eyes; CD, copulatory

ducts; CO, copulatory opening; cl/cw, carapace length/carapace width; DTA, distal tegular apophysis; DTiA, dorsal tibial apophysis; LTA, retrolateral tegular apophysis; MOQ, median ocular quadrangle; PLE, posterior lateral eyes; PME, posterior median eyes; RCF, retrolateral cymbial fold; S, spermatheca; sl/sw, sternum length/sternum width; VTA, ventral tegular apophysis.

Institutional abbreviations. AM, Australian Museum, Sydney; BMNH, British Museum of Natural History, QM, Queensland Museum, Brisbane.

SYSTEMATICS

Habronestes L. Koch, 1872

Habronestes L. Koch, 1872: 299; Jocqué, 1991: 56; Jocqué, 1995: 143; Baehr, 2003c.

TYPE SPECIES. *Habronestes striatipes* L. Koch, 1872 by subsequent designation of Petrunkevitch (1928). Following Jocqué, 1991, *H. striatipes* L. Koch, 1872 is taken as the type species.

DIAGNOSIS. Cymbium with large, retrolateral fold (RCF). Palp with sickle-shaped VTA; DTA with long stalk and curled end covered with spicules, which functions as a conductor; embolus thin, semicircular, embolus base flattened. Tarsi I-IV with 2 rows of short stout ventral spines.

Baehr (2003c) provided a detailed description of the genus and divided the species into three groups based on their widely differing eye patterns (figs 7-13): the *H. australiensis*-group (fig.7), the *H. macedonensis-group* (Fig. 2A, fig. 8) and the *H. pictus*- group (figs 9, 10).

Habronestes maccdonensis-group

DIAGNOSIS. Eyes in 2 rows, both rows procurved, AME largest. Femur III, IV with a row of 3-6 stout dorsal spines at distal end; patella III, IV with 1 irregular longitudinal row of stout spines prolaterally. Abdomen with 1–4 pairs of white spots on anterior part and 1 or 2 in front of spinnerets or with chevrons. For a complete description of the group see Baehr, 2003c.

KEY TO SPECIES OF THE *HABRONESTES MACEDONENSIS*-GROUP OF QUEENSLAND AND NEW SOUTH WALES

1. Males 2
   Females 21
2. Palpal patella with dorsal apophysis (Fig. 6D, fig. 30) 3
   Palpal patella without dorsal apophysis 7
3. Basal segment of chelicerae with horizontal boss (Fig. 2F) 4
   Basal segment of chelicerae without horizontal boss (Fig. 2E) 5
4. LTA retrolaterally directed, with u-shaped tip (Fig. 7C) ..... *H. gumbardo* sp. nov.
   LTA distally directed, tip not u-shaped (Fig. 7A) ..... *H. boq* sp. nov.
5. Carapace pale yellow with dark cephalic area (Figs 2I, J) 6
   Carapace uniformly dark (figs 16, 29) ..*H. hebronae* Baehr
6. Carapace narruw, with two dark lateral bands that surround fovea as a triangle, but do not reach posterior margin of carapace (Figs 2H, J) ..... *H. dickmani* sp. nov.
   Carapace broad, with two dark lateral bands that unite just behind fovea and reach posterior margin of carapace (Figs 2G, I) ..... *H. powelli* sp. nov.
7. Cymbium densely covered with long bristles (Figs 3E, F) ..... *H. jankoe* sp. nov.
   Cymbium covered with short bristles (Figs 3A-D) 8
8. LTA fan-shaped, covered with small spicules (fig. 40) ..... *H. macedonensis* (Hogg)
   LTA not fan-shaped 9
9. Tibia and Metatarsus I with a ventral band of short conical setae. 10
   Tibia and Metatarsus I without a ventral band of short conical setae. 12
10. Tibia and proximal part of metatarsus I with a ventral band of short conical setae; cymbial fold as long as whole cymbium (Figs 7E, F) ..... *H. clousoni* sp. nov.
    Distal part of tibia and metatarsus I with a ventral band of short conical setae; cymbial fold half as long as cymbium (Figs 4A, B, E, F) 11
11. VTA 3 x as long as wide, slender; LTA tip with two long apophyses, distal one serrated (Fig. 4E, F) ..... *H. tillmani* sp. nov.
    VTA 2 x as long as wide, hroad; LTA tip with long retrolaterally directed hook (Fig. 4A, B) ..... *H. drummoud* sp. nov.
12. Cymbial tip with extremely strong spines; LTA with comb-like structure at tip (Fig. 5E,) ..... *H. archiei* sp. nov.
    Cymbial tip with normal spines; LTA without comb-like structure at tip (Figs 3C, 5C) 13
13. VTA very short, about as long as wide; LTA half-moon-shaped with dorsal spine (figs 44, 45) . . *H. ungari* Baehr
    VTA much longer, at least twice as long as wide; LTA not half moon-shaped (Figs 3C, 5C) 14
14. LTA with long retrolaterally directed basal spine or apophysis (Figs 4C, 6E, fig. 27). 15
    LTA without long retrolaterally directed basal spine or apophysis (Figs 3A, C, 5A, C, fig. 42). 17
15. VTA, about 3 times as long as wide, slender, half-moon-shaped (Fig. 6E. fig. 27). 16
    VTA much broader, straight (Figs 4C) ..... *H. gayndah* sp. nov.
16. Bulb small, about half of cymbium length; LTA with basal spine (Fig. 6E) ..... *H. hooperi* sp. nov.

Bulb larger, about 2/3 of cymbium length; LTA with complex basal apophysis (fig. 27)..... *H. rawlinsonae* Baehr

17. DTiA short and rounded or spatulate (fig. 43, Fig. 3D) 18

DTiA bifurcate (Fig. 3B, 5B, D) 19

18. DTiA short and rounded (fig. 43).... *H. weelahensis* Baehr

DTiA spatulate (Fig. 3D)..... *H. gallowayi* sp. nov.

19. DTiA bifureate, v-shaped; LTA with distal tip twisted, hood-shaped (Fig. 3A, B) ..... *H. braemar* sp. nov.

DTiA bifurcate, u-shaped, ventral part an erect spine (Fig. 5B, D); LTA with distal tip hook-shaped 20

20. Abdomen with 1 pair of white spots dorsally and 2 spots in front of spinnerets (Fig. 2D); LTA with broad tip (Fig. 5C, D)..... *H. ulrichi* sp. nov.

Abdomen with 2 pairs of white spots dorsally and 1 spot in front of spinnerets (Fig. 1B); LTA with narrow tip (Fig. 5A, B).. ..... *H. diocesegrafion* sp. nov.

21. Epigyne with w-shaped scapus (fig. 35) .....*H. macedonensis* (Hogg)

Epigyne without w-shaped scapus (Fig. 9A, figs 31-34) 22

22. Epigyne with a single copulatory opening (Fig. 8A, C, E) 23

Epigyne with paired copulatory openings (Fig. 9A, C, E, figs 31, 33)..... 25

23. Copulatory opening slit-like, located at base of epigastric fold (Fig. 8E, F).....*H. drummond* sp. nov.

Copulatory opening broadly oval (Fig. 8A, C)..... 24

24. Spermathecae pear-shaped (Fig. 8A, B)... *H. ungari* Baehr

Spermathecae globular (Fig. 8C, D)... *H. jankae* sp. nov.

25. Spematheeae coiled (Fig. 9E, F)... *H. clausoni* sp. nov.

Spermathecae not coiled (Fig. 9B, D, figs 32, 34) ... 26

26. Copulatory openings slit-like (Fig. 9C).. *H. powelli* sp. nov.

Copulatory openings not slit-like (Fig. 9A, figs 31, 33) 27

27. Copulatory openings broadly triangular (Fig. 9A) .....*H.boq* sp. nov.

Copulatory openings oval or pear-shaped (figs 31, 33) 28

28. Copulatory openings long and oval; copulatory ducts s-shaped (figs 31, 32)..... *H. rawlinsonae* Baehr

Copulatory openings broadly pear-shaped; copulatory ducts sausage-like (figs 33, 34) ... *H. hebronae* Baehr

Habronestes archiei sp. nov.
(Figs 1D, 2E, 5E-F, 10D)

ETYMOLOGY. In honour of Archie Nahman, the first son of Dr Helen Nahrung and Dr Owen Seeman, the Arachnology Collection Manager of the Queensland Museum.

MATERIAL. HOLOTYPE. Queensland: ♂, Garfield, 23°18'S 145°58'E, 13 Jan 1999, T. Churchill, pitfall (QM S70004). OTHER MATERIAL. Queensland: 2♂♂, Garfield, 23°18'S 145°58'E, 13 Jan 1999, T. Churchill, pitfall (QM S70005, S70006).

DIAGNOSIS. This species resembles *H. gayndah* sp. nov. in dorsal abdominal pattern and the general shape of the male palp, but can be distinguished by the extremely strong distal spines at the tip of the cymbium and the comb-like structure at the tip of the retrolateral tegular apophysis (LTA) (Fig. 5E).

DESCRIPTION. *Male* (holotype). 5.88 long. Carapace 3.08 long, 2.12 wide, cl/cw 1.45, 1.28 high; caput 1.38 wide; sternum 1.40 long, 1.12 wide, sl/sw 1.25; abdomen 2.80 long, 2.00 wide.

Colour in alcohol. Carapace orange brown with dark fovea and dark bifurcate patches in front; sternum and chelicerae medium brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with 4-5 pairs of white spots in a line and 2-3 spots in front of spinnerets. Legs medium brown; coxae I-IV white; trochantera I-IV brown; femur I dark brown, II-IV with proximal part white, distal part dark brown; tibiae I-IV with brown lateral stripes.

Eyes. Nearly equal sized, AME largest. Eye group width 0.67 of caput width. Diameters: AME 0.22; ALE 0.20; PME 0.19; PLE 0.22. Interspaces: AME-AME 0.02; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.12; ALE-PLE 0.04. MOQ: AME-PME 0.46; AME-AME 0.46; PME-PME 0.46. Clypeus 0.5 high.

Chelicerae basal segment *(Fig.* 2E), typical for genus with lateral condyle and rows of hairs bordering inner margin.

Legs. Femora III, IV with a row of 5–6 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally.

Male palp. (Fig. 5E-F) Cymbium with weak dorsal apical scopula and few extremely strong spines apically; retrolateral fold flat, 1/2 of cymbium length. LTA a broad, distally directed stalk with basoretrolateral apophysis; tip with comb-like structure. VTA long, relatively straight, with rounded tip, originating basally. DTiA tripartite. Femur with 3 stout dorsal spines.

Female unknown.

DISTRIBUTION. Known only from the type locality in central Queensland (Fig. 10D).

Habronestes boq sp. nov.
(Figs 1A, 7A–B, 9A–B, 10B)

ETYMOLOGY. In honour of the Bank of Queensland, which supported the 'Name a Spider' project.

MATERIAL. HOLOTYPE. Queensland: ♂, Expedition Ra. NP, 'Amphitheatre Camp', 560m, 25°12'S,

148°59'E, 17-19 Dec 1997, G. Monteith, D. Cook, G. Thompson, pitfall (QM S47524). OTHER MATERIAL. Queensland: 1 ♀, Dotswood, 19°28'S, 146°27'E, Feb 1999, T. Churchill, pitfall (QM S72779).

DIAGNOSIS. The males and female were not collected together, but are matched on the basis of the identical colour patterns of their abdomina and legs. This species resembles *H. gumbardo* sp. nov. in abdominal pattern and the general shape of the male palp but can be separated by the folded retrolateral tegular apophysis (LTA). Females can be distinguished easily by their paired, triangular copulatory openings (Fig. 9A).

DESCRIPTION. *Male* (holotype). 6.68 long. Carapace 3.48 long, 2.72 wide, cl/ew 1.28, 1.68 high; caput 1.60 wide; sternum 1.56 long,1.56 wide, sl/sw 1.00; abdomen 3.20 long, 2.36 wide.

Colour in alcohol. Carapace, sternum and chelicerae orange brown; endites and labium yellow, distally white. Abdomen sepia brown, dorsally with 4 pairs of white spots, nearly in line, and an undulate patch in front of spinnerets; laterally with an elongate horizontal white stripe reaching front of abdomen; ventrally with 1 longitudinal white stripe from epigastric fold to tracheal spiracle. Legs yellow; coxae I-IV white; trochantera I-IV white; femora I-IV with proximal part white shading to dark brown distally; tibiae I-IV with brown lateral stripes.

Eyes. AME largest. Eye group width 0.61 of caput width. Diameters: AME 0.27; ALE 0.18; PME 0.10; PLE 0.18. Interspaces: AME-AME 0.02; AME-ALE 0.06; PME-PME 0.14; PME-PLE 0.18; ALE-PLE 0.06. MOQ: AME-PME 0.56; AME-AME 0.56; PME-PME 0.54. Clypeus 0.96 high.

Basal segment of chelicera with a horizontal boss as in Fig. 2F, lateral condyle and rows of hairs, bordering inner margin. Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with a row of 3-4 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally. Tibia and proximal part of metatarsus I with a band of short conical setae ventrally.

Male palp. (Fig. 7A, B) Cymbium with few spines apically, retrolateral cymbial fold deep, 2/3 of cymbium length. LTA a broad, distally directed stalk, tip folded. VTA long, sickle-shaped, originating basally. Tibia short, DTiA tiny, bifurcate. Palpal patella with stout, conical, dorsal apophysis.

Female. 7.96 long. Carapace 3.76 long, 2.80 wide, cl/ew 1.34, 2.12 high; caput 1.76 wide; sternum 1.68 long, 1.68 wide, sl/sw 1.00; abdomen 4.20 long, 3.32 wide.

Colour in alcohol. Carapace, sternum and chelicerae orange brown; endites and labium yellow, distally white. Abdomen sepia brown, dorsally with 4 pairs of white spots nearly in line and an undulate spot in front of spinnerets; laterally with an elongate horizontal white stripe reaching front, ventrally with a longitudinal white stripe from epigastric fold to tracheal spiracle. Legs yellow; coxae I-IV white; trochantera I-IV white; femora I-IV with proximal part white shading to dark brown distally; tibiae I-IV with brown lateral stripes.

Eyes. AME largest. Eye group width 0.64 of caput width. Diameters: AME 0.28; ALE 0.20; PME 0.22; PLE 0.24. Interspaces: AME-AME 0.06; AME-ALE 0.06; PME-PME 0.16; PME-PLE 0.16; ALE-PLE 0.06. MOQ: AME-PME 0.56; AME-AME 0.62; PME-PME 0.60. Clypeus 0.98 high.

Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with a row of 3-4 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally.

Epigyne. (Fig. 9A, B) with paired, trianglular copulatory openings, short, parallel directed copulatory ducts and widely separated, oval spermatheeae.

DISTRIBUTION. Eastern Queensland (Fig. 10B).

Habronestes braemar sp. nov.
(Figs 3A-B, 10D)

ETYMOLOGY. A noun in apposition taken from the type locality.

MATERIAL. HOLOTYPE. Queensland: ♂, Braemar State forest, 27°13'S, 150°50'E, 4-8 Nov 1980, QM, G.B.S.R.M. (QM S55169). OTHER MATERIAL. Queensland: 1 ♂, Braemar Forest Station, Brigalow, 380m, 9190, 27°13'S, 150°50'E, 2-4 Mar 2000, G. Monteith (QM S71642); 1 ♂, Lake Broadwater, via Dalby, gravel ridge 27°21'S, 151°07'E, 25-27 Jan 1985, V. Davies, J. Gallon, pitfall (QM S72777).

DIAGNOSIS. This species resembles *H. gallowayi* sp. nov. in the general shape of the male palp but can be distinguished by the bifurcate shape of the dorsal tibial apophysis.

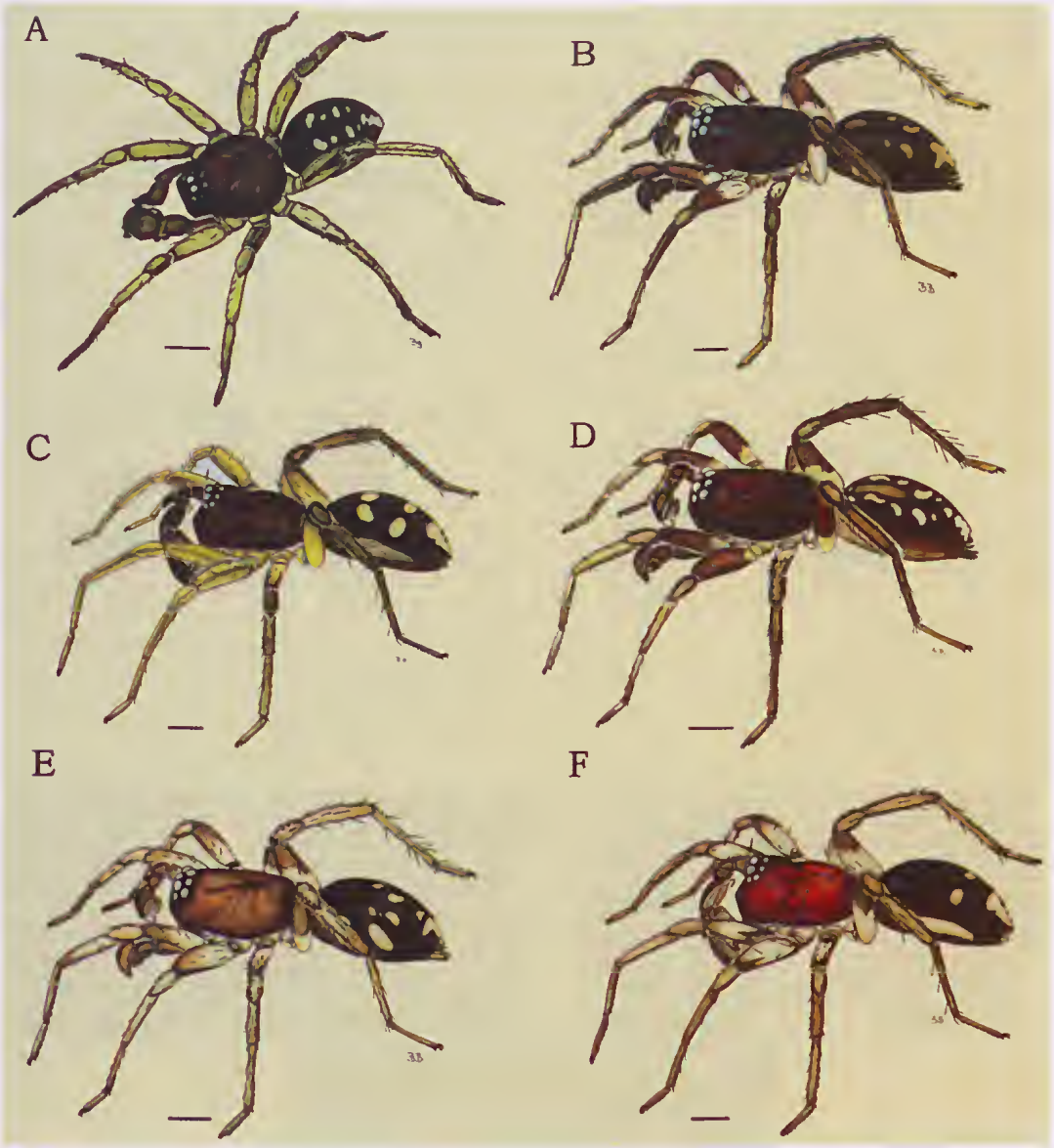

FIG. 1. *Habronestes* species, habitus. A, *H. boq* sp. nov.; B, *H. diocesegrafton* sp. nov.; C, *H. clausoni* sp. nov.; D, *H. archiei* sp. nov.; E, *H. hooperi* sp. nov.; F, *H. tillmani* sp. nov.

DESCRIPTION. *Male* (holotype). 6.00 long. Carapace 3.12 long, 2.24 wide, cl/cw 1.39, 1.40 high; caput 1.34 wide; sternum 1.44 long, 1.28 wide, sl/sw 1.13; abdomen 2.88 long, 2.12 wide.

Colour in alcohol. Carapace, sternum and chelicerae dark reddish brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with 4 pairs of white spots nearly in line, and an undulate patch in front of spinnerets; laterally with 2 white spots, anterior small, posterior elongate. Legs medium brown; coxae I-IV white; trochantera I-IV brown; femur I dark brown, II-IV with proximal part white, distal part dark brown; tibiae I-IV with brown lateral stripes.

Sternum. Densely covered with long setae.

Eyes. AME largest. Eye group width 0.64 of caput width. Diameters: AME 0.21; ALE 0.18; PME 0.18; PLE 0.18. Interspaces: AME-AME 0.02; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.12; ALE-

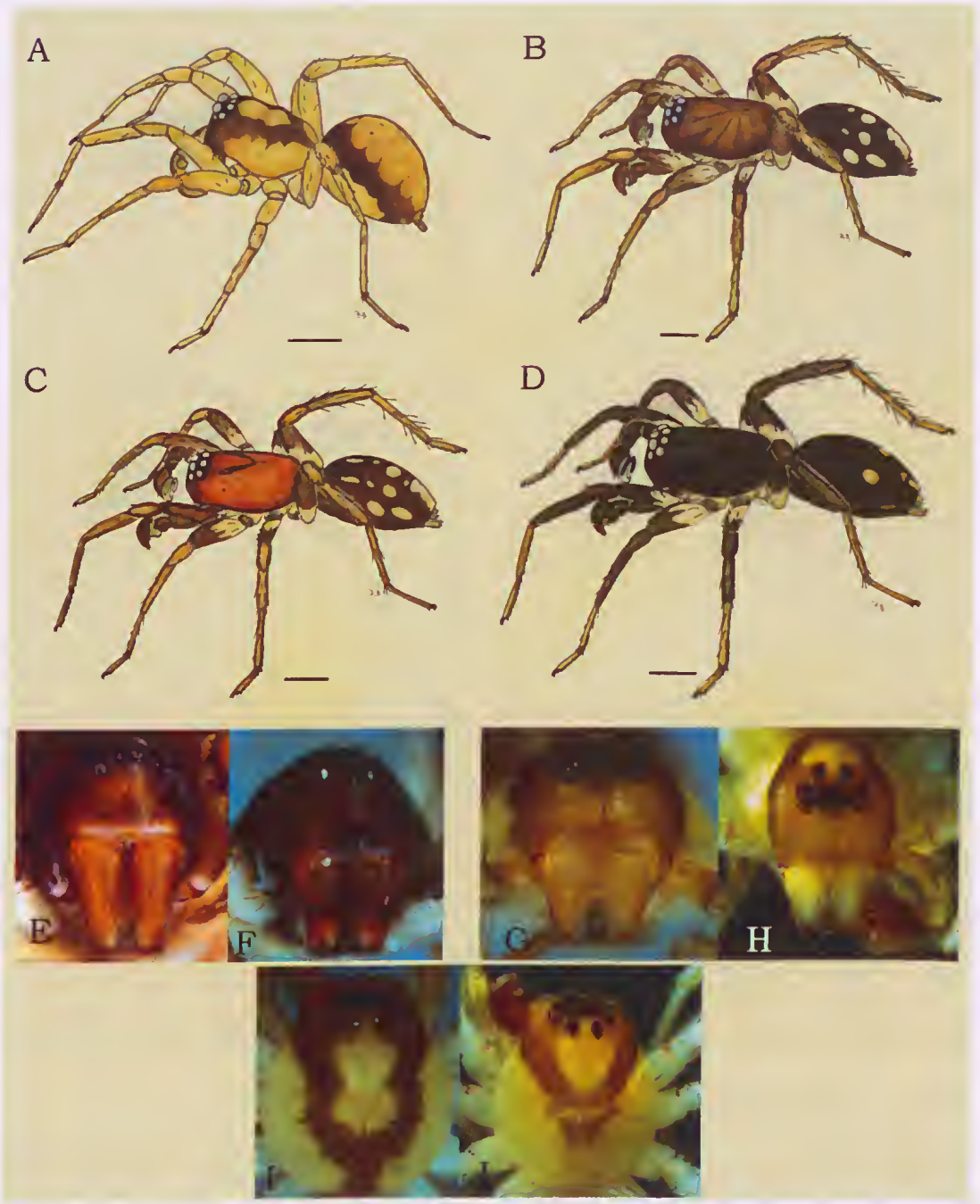

FIG. 2. *Habronestes* species, A-D, habitus; E-H, faces; I-J, carapace. A, *H. powelli* sp. nov.; B, *H. gallowayi* sp. nov.; C, *H. jankae* sp. nov.; D, *H. ulrichi* sp. nov.; E, *H. archiei* sp. nov.; F, *H. boq* sp. nov.; G-I, *H. powelli* sp. nov.; H-J, *H. dickmani* sp. nov.

PLE 0.04. MOQ: AME-PME 0.46; AME-AME 0.44; PME-PME 0.44. Clypeus 0.58 high.

Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with a row of 5-6 stout dorsal spines at distal end; patellae III, IV with 1 irregular longitudinal row of stout spines prolaterally; metatarsi I, II with 2 rows of spines ventrally.

Male palp. (Fig. 3A-B) Cymbium with weak dorsal scopula and few spines apically; tip shorter than wide; retrolateral cymbial fold flat, 1/2 of cymbium length. LTA a cylindrical, distally directed stalk; tip twisted, hood-shaped. VTA short, relatively straight, with sharp tip, originating prolaterally. Tibia elongate; DTiA bifurcate.

Female unknown.

DISTRIBUTION. Brigalow woodland in south-eastern Queensland (Fig. 10D).

Habronestes clausoni sp. nov.
(Figs 1C, 7E–F, 9E–F, 10D)

ETYMOLOGY. In honour of Owen Carl Clauson, a young, passionate, Australian spider collector.

MATERIAL. HOLOTYPE. Queensland: ♂, Astrebla Downs NP, 24°13' S, 140°34' E, Apr1997, L. Gibson, pitfall (QM S68900). ALLOTYPE. Queensland: ♀, Astrebla Downs NP, 24°13' S, 140°34' E, Apr 1997, L. Gibson, pitfall (QM S68908). OTHER MATERIAL. Queensland: 9♂♂, 3♀♀, same as holotype (QM S68901- S68907, S68909, S68910).

DIAGNOSIS. This species can be distinguished from all other members of the *H. macedonensis*-group by the form of the cymbium which is sickle-shaped in lateral view and has a deep retrolateral cymbial fold that is as long at the cymbium itself (Fig. 7F). Females can be easily separated by their elongated and coiled copulatory ducts (Fig. 9F).

DESCRIPTION. *Male* (holotype). 6.60 long. Carapace 3.48 long, 2.40 wide, cl/cw 1.45, 1.76 high; caput 1.60 wide; sternum 1.40 long, 1.36 wide, sl/sw 1.03; abdomen 3.12 long, 2.32 wide.

Colour in alcohol. Carapace, sternum and chelicerae reddish brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with 2 pairs of white spots and a spot in front of spinnerets; laterally with an elongate horizontal white stripe. Legs pale brown; coxae I-IV white; trochantera I-IV white; femora I-IV with proximal part white shading to dark brown distally; tibiae I-IV with brown lateral stripes. Carapace raised at front; sternum densely covered with long setae.

Eyes. AME largest. Eye group width 0.63 of caput width. Diameters: AME 0.28; ALE 0.16; PME 0.20; PLE 0.22. Interspaces: AME-AME 0.06; AME-ALE 0.04; PME-PME 0.12; PME-PLE 0.16; ALE-PLE 0.04. MOQ: AME-PME 0.52; AME-AME 0.62; PME-PME 0.52. Clypeus 0.92 high.

Legs. Femora III, IV with a row of 3-4 stout dorsal spines at distal end; patellae III, IV with 1 irregular longitudinal row of stout spines prolaterally. Tibia and proximal part of metatarsus I with a band of short conical setae ventrally.

Male palp (Fig. 7E–F). Cymbium in lateral view sickle-shaped, with few spines apically; retrolateral fold deep, as long as whole cymbium. LTA a long, distally directed stalk; tip with short retrolateral spine and two prolateral wing-shaped apophyses. VTA long, sickle-shaped, originating retrolaterally. Tibia short; DTiA spatulate.

Female. (allotype) 9.16 long. Carapace 4.80 long, 2.80 wide, cl/cw 1.71, 2.04 high; caput 2.08 wide; sternum 1.60 long, 1.48 wide, sl/sw 1.08; abdomen 4.36 long, 3.32 wide.

Colour in alcohol. As in male.

Eyes. AME largest. Eye group width 0.55 of caput width. Diameters: AME 0.32; ALE 0.20; PME 0.20; PLE 0.20. Interspaces: AME-AME 0.06; AME-ALE 0.06; PME-PME 0.26; PME-PLE 0.18; ALE-PLE 0.06. MOQ: AME-PME 0.62; AME-AME 0.70; PME-PME 0.66. Clypeus 1.04 high.

Legs. As in male but tibia and proximal part of metatarsus I without a band of short conical setae ventrally. Female palpal tibia and tarsus with a pro- and retrolateral row of long slightly bent setae.

Epigyne. (Fig. 9E–F) with paired, broad-oval copulatory openings; copulatory ducts elongated and coiled, ending in small slightly separated spermathecae.

DISTRIBUTION. Known only from the type locality in western Queensland (Fig. 10D).

Habronestes dickmani sp. nov.
(Figs 2H, J, 6A-B, 10E)

ETYMOLOGY. In honour of Dr Chris Dickman, who collected the holotype and most of the material examined.

MATERIAL. HOLOTYPE. Queensland: ♂, Ethabuca Stn., Simpson Desert, 23°46'S, 138°28'E, Nov 1994, C. Dickman, pitfall (QM S71682). OTHER MATERIAL. Queensland: 3 ♂♂, Charleville, Merigol, 25km NW, 10126, 25°16'S, 146°02'E, 3-6 May 2001, G. Monteith, dung trap (QM S 71667); 1 ♂, Charleville, 10907,

Merigol, site 7 mulga, 26°48'S, 145°49'E, Apr 2001, T. Beutel, pitfall (QM S63541); 10 ♂♂, Ethabuca Stn., Simpson Desert, 23°46'S, 138°49'E, Jun-Jul 1997, C. Dickman, pitfall (QM S71674); 3 ♂♂, same May 1991 (QM S71681); 1 ♂, same, Nov 1994 (QM S71683); 1 ♂, Mulga gradient, near Tylungra, 26°04'S, 143°27'E, Oct 1995, J. Landsberg, pitfall (QM S71680).

DIAGNOSIS. This species resembles *H. powelli* sp. nov. in body shape and the general structure of the male palp, but can be distinguished by a less developed dorsal apophysis on the palpal femur and the colour and form of the carapace. The cephalic area of *H. dickmani* is narrower and has a dark triangular marking that surrounds the fovea but does not reach the posterior margin of the carapace (Fig. 2H, J).

DESCRIPTION. *Male* (holotype). 4.08 long. Carapace 2.24 long, 1.56 wide, cl/cw 1.44, 0.92 high; caput 0.96 wide; sternum 1.00 long, 0.92 wide, sl/sw 1.09; abdomen 1.84 long, 1.36 wide.

Colour in alcohol. Carapace yellow with a dark cephalic area that surrounds fovea as a triangle but does not reach posterior margin of carapace; sternum and chelicerae yellow; endites and labium yellow, distally white. Abdomen pale, dorsally with 2 pairs of white spots and a spot in front of spinnerets; laterally and ventrally pale; with light brown ring around spinnerets and tracheal spiracle. Legs pale.

Eyes. AME largest. Eye group width 0.73 of caput width. Diameters: AME 0.21; ALE 0.14; PME 0.14; PLE 0.14. Interspaces: AME-AME 0.02; AME-ALE 0.04; PME-PME 0.1; PME-PLE 0.08; ALE-PLE 0.04. MOQ: AME-PME 0.4; AME-AME 0.44; PME-PME 0.38.Clypeus 0.48 high.

Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with 2 dorsal spines at distal end; patellae III, IV with 1 irregular longitudinal row of stout spines prolaterally, consisting of only 3 spines. Tibia 1 with a band of short conical setae ventrally.

Male palp. (Fig. 6A-B) Cymbium tip longer than wide, slender with few spines; retrolateral cymbial fold deep, 3/4 of cymbium length. LTA a cylindrical, distally directed stalk, tip scooped, with a long retrolateral spine. VTA long, sickle-shaped, with sharp tip, originating basally. Tibia short; DTiA absent. Palpal patella with stout, conical, dorsal apophysis.

VARIATION. The abdominal pattern is variable. It can consist of 2 pairs of pale spots (as in the holotype) or 2 pairs of brown chevrons. Female unknown.

DISTRIBUTION. Dunes and mulga in central Queensland (Fig. 10E).

Habronestes diocesegrafton sp. nov.
(Figs 1B, 5A–B, 10C)

ETYMOLOGY. In honour of the Anglican Diocese of Grafton, which supported the 'Name a Spider' project.

MATERIAL. HOLOTYPE. New South Wales: ♂, Carce 30°03' S, 148°31' E, Feb 2001, I. Oliver, pitfall (AM KS80830).

DIAGNOSIS. This species resembles *H. ulrichi* sp. nov. in the general shape of male palp, but can be distinguished by the narrow tip of retrolateral tegular apophysis (LTA) and the broader median tegular apophysis (VTA) (Fig. 5A).

DESCRIPTION. *Male* (holotype). 5.56 long. Carapace 2.76 long, 1.92 wide, cl/cw 1.44, 1.12 high; caput 1.18 wide; sternum 1.28 long, 1.16 wide, sl/sw 1.10; abdomen 2.80 long, 1.76 wide.

Colour in alcohol. Carapace, sternum and chelicerae sepia brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with 2-3 pairs of white spots and an elongate and undulate spot in front of spinnerets; laterally with a white patch. Legs medium brown; coxae I-IV white; trochantera I-IV brown; femora I-IV with proximal part white, distal part dark brown; tibiae I-IV with brown lateral stripes. Sternum densely covered with long setae.

Eyes. AME largest. Eye group width 0.66 of caput width. Diameters: AME 0.19; ALE 0.16; PME 0.16; PLE 0.16. Interspaces: AME-AME 0.08; AME-ALE 0.06; PME-PME 0.10; PME-PLE 0.10; ALE-PLE 0.06. MOQ: AME-PME 0.46; AME-AME 0.42; PME-PME 0.42. Clypeus 0.46 high.

Legs. Femora III, IV with a row of 5-6 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally; metatarsi I, II with 2 rows of spines ventrally.

Male palp. (Fig. 5A–B) Cymbium with weak dorsal apical scopula and few spines apically; tip shorter than wide; retrolateral cymbial fold flat, 1/2 of cymbium length. LTA a long, distally directed stalk; tip tiny, hook-shaped. VTA sickle-shaped, with broadly rounded tip that is at least 1/4 as long as width of embolus base, originating basally. DTiA bifurcate.

Female unknown.

DISTRIBUTION. Known only from the type locality in northern New South Wales (Fig. 10♡)

Habronestes drummond sp. nov.
(Figs 4A–B, 8E–F, 10F)

ETYMOLOGY. A noun in apposition taken from the type locality.

MATERIAL. HOLOTYPE. Queensland: ♂, Drummond Ra. summit, 920m, open forest, 10005, 23°32'S, 147°18'E, 18 Dec 2000-27 Mar 2001, G. Monteith, D. Cook, pitfall (QM S71631). ALLOTYPE. Queensland: ♀, same as holotype, 9822, 25 Oct-17 Dec 2005 (QM S71629). OTHER MATERIAL. 2 ♂♂, same as holotype, 10004, 18 Dec 2000-27 Mar 2001 (QM S71630).

DIAGNOSIS. This species resembles *H. gayndah* sp. nov. in abdominal pattern and the general shape of the male palp, but can be distinguished by the absence of a long retrolateral spine at the base of the retrolateral tegular apophysis (LTA) (Fig. 4A). Females of *H. drummond* can be separated from all others treated here by having a slit-like copulatory opening along the epigastric fold (Fig. 8F).

DESCRIPTION. *Male* (holotype). 6.76 long. Carapace 3.36 long, 2.08 wide, cl/cw 1.62, 1.28 high; caput 1.28 wide; sternum 1.52 long, 1.28 wide, sl/sw 1.19; abdomen 3.40 long, 2.20 wide.

Colour in alcohol. Carapace, sternum and chelicerae sepia brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with 3 pairs of white spots and 1-2 spots in front of spinnerets; laterally with 2 elongate white spots. Legs medium brown; coxae I-IV white; trochantera I-IV brown; femur I dark brown, II-IV with proximal part white, distal part dark brown; tibiae I-IV with brown lateral stripes. Sternum densely covered with long setae.

Eyes. AME largest. Eye group width 0.66 of caput width. Diameters: AME 0.23; ALE 0.16; PME 0.18; PLE 0.16. Interspaces: AME-AME 0.02; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.10; ALE-PLE 0.04. MOQ:AME-PME 0.46; AME-AME 0.48; PME-PME 0.44. Clypeus 0.50 high.

Abdomen. Tracheal spiracle small, slit-like, with sclerotised cover. Area between epigastric fold and tracheal spiracle covered with short, stout bristles.

Legs. Femora III, IV with a row of 5-6 stout dorsal spines at distal end; patellae III, IV with 1 irregular longitudinal row of stout spines prolaterally. Distal part of tibia and metatarsus I with a band of short conical setae ventrally.

Male palp. (Fig. 4 A-B). Cymbium with weak scopula and few spines apically; retrolateral fold flat, 1/2 of cymbium length. LTA a short, broad, distally directed stalk; tip with long, retrolaterally directed hook, covered with tiny spikes. VTA short, sickle-shaped, with sharp tip, originating prolaterally. Tibia short; DTiA short, t-shaped.

Female. (allotype) 8.80 long. Carapace 4.40 long, 2.92 wide, cl/cw 1.51, 1.60 high; caput 1.70 wide; sternum 1.92 long, 1.68 wide, sl/sw 1.14; abdomen 4.40 long, 2.80 wide.

Colour in alcohol. Same as in male.

Eyes. AME largest. Eye group width 0.65 of caput width. Diameters: AME 0.28; ALE 0.24; PME 0.23; PLE 0.24. Interspaces: AME-AME 0.06; AME-ALE 0.04; PME-PME 0.10; PME-PLE 0.14; ALE-PLE 0.04. MOQ: AME-PME 0.64; AME-AME 0.62; PME-PME 0.56. Clypeus 0.68 high.

Legs. Same as in male but without a band of short conical setae on distal part of tibia and metatarsus I. Female palpal tibia and tarsus with a prolateral row of long, slightly bent setae.

Epigyne. (Fig. 8E–F) a concave circle, copulatory opening slit-like along epigastric fold, barely visible. Vulva with short, thin copulatory ducts and oval, contiguous spermatheeae in a v-shaped position.

DISTRIBUTION. Known only from the type locality in central Queensland (Fig. 10F).

Habronestes gallowayi sp. nov.
(Figs 2B, 3C–D, 10B)

ETYMOLOGY. The specific name is a patronym in honour of Dr Ian Galloway, the CEO of the Queensland Museum, who supported the 'Name a Spider' project.

MATERIAL. HOLOTYPE. Queensland: 1♂, Nipping Gully, 240m, 25°42'S, 151°26'E, 18 Dec 1998-26 Jan 1999, G. Monteith, intercept trap (QM S49819). OTHER MATERIAL. Queensland: 1♂, Mount Gavial, 3km SSW, 320m, 23°37'S, 150°28'E, 14 Mar 1999, D. Cook, pitfall (QM S51160).

DIAGNOSIS. This species resembles *H. jankae* sp. nov. in abdominal pattern and the general shape of the male palp, but can be distinguished by the spatulate shape of the dorsal tibial apophysis.

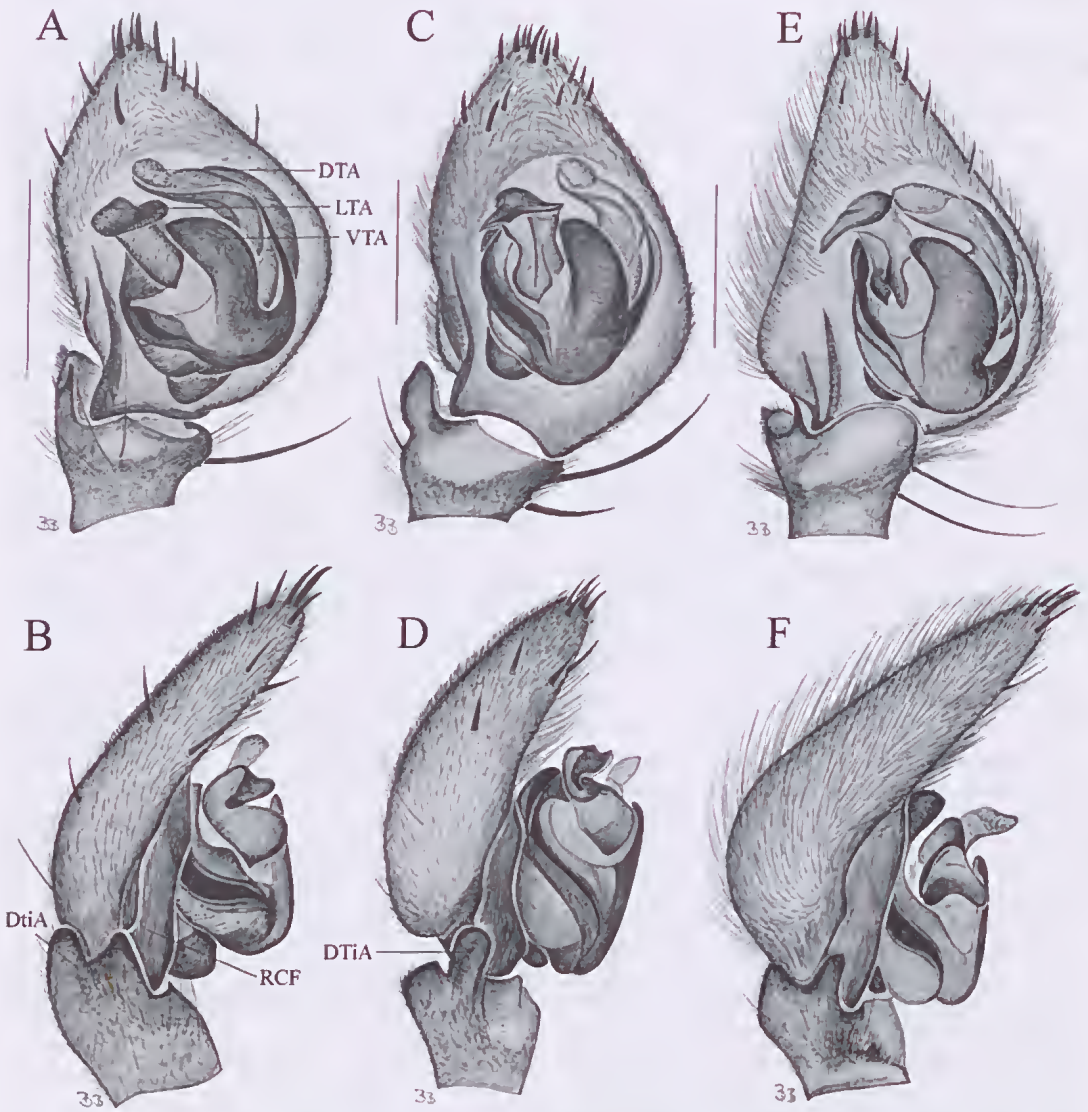

FIG. 3. *Habronestes* species, male palps, ventral view (top), lateral view (bottom). A-B, *H. braemar* sp. nov.; C-D, *H. gallowayi* sp. nov.; E-F, *H. jankae* sp. nov.

DESCRIPTION. *Male* (holotype). 7.24 long. Carapace 3.88 long, 2.60 wide, cl/cw 1.49; caput 1.44 wide, 1.24 high; sternum 1.72 long, 1.56 wide, sl/sw 1.10; abdomen 3.36 long, 2.16 wide.

Colour in alcohol. Carapace, sternum and chelicerae sepia brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with 3 pairs of white spots and 1-2 spots in front of spinnerets; laterally with 2 white spots, anterior small, posterior elongate. Legs pale brown; coxae I-IV white; trochantera I-IV brown; femora I-IV with proximal part white, distal part dark brown; tibiae I-IV with brown lateral stripes (Fig. 2B).

Eyes. AME largest. Eye group width 0.65 of caput width. Diameters: AME 0.22; ALE 0.16; PME 0.20; PLE 0.18. Interspaces: AME-AME 0.06; AME-ALE 0.04; PME-PME 0.10; PME-PLE 0.12; ALE-PLE 0.04. MOQ: AME-PME 0.52; AME-AME 0.50; PME-PME 0.50. Clypeus 0.64 high, with a field of short, stout spines.

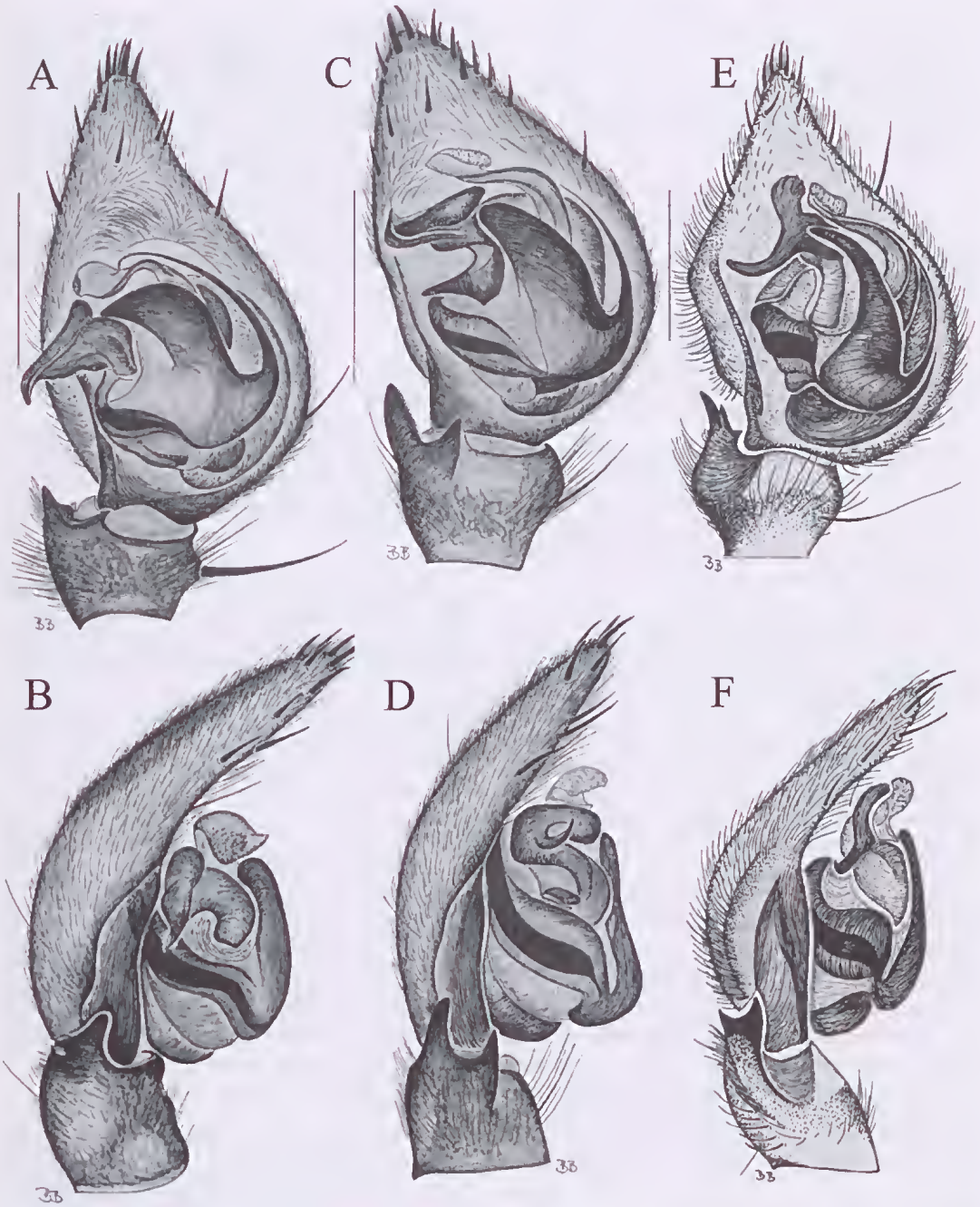

FIG. 4. *Habronestes* species, male palps, ventral view (top), lateral view (bottom). A-B, *H. drummond* sp. nov., C-D, *H. gayndah* sp. nov.; E-F, *H. tillmani* sp. nov.

Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with a row of 5-6 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally.

Male palp. (Fig. 3C, D) Cymbium with long dorsal scopula and few spines apically, retrolateral cymbial fold flat, 1/2 of cymbium length. LTA a broad, distally directed stalk, tip folded with retrolateral spine. VTA short, relatively straight,

with rounded tip. Embolus originates prolaterally. DTiA spatulate.

Female unknown.

DISTRIBUTION. South-eastern Queensland in open eucalyptus forest (Fig. 10B).

Habronestes gayndah sp. nov.
(Figs 4C-D, 10F)

ETYMOLOGY. A noun in apposition taken from the type locality.

MATERIAL. HOLOTYPE. Queensland: 1♂, Mount Gayndah summit, open forest, 340m, 25°36'S, 151°32'E, Jan 2001, B. Baehr, hand coll. (QM S71639). OTHER MATERIAL. Queensland: 1♂, same, 7589, 18 Dec 1998-27 Jan 1999, G. Monteith (QM S55163).

DIAGNOSIS. This species resembles *H. drummond* sp. nov. in abdominal pattern and the general shape of the male palp, but can be distinguished by having a long, retrolateral spine at the base of the retrolateral tegular apophysis (LTA) (Fig. 4C-D).

DESCRIPTION. *Male* (holotype). 5.44 long. Carapace 2.96 long, 2.08 wide, cl/cw 1.42, 1.36 high; caput 1.28 wide; sternum 1.36 long, 1.20 wide, sl/sw 1.13; abdomen 2.48 long, 1.68 wide.

Colour in alcohol. Carapace orange brown with dark fovea and bifurcate patches in front; sternum and chelicerae medium brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with 3 or 4 pairs of white spots and 2 or 3 spots in front of spinnerets; laterally with a white spot; ventrally pale brown. Legs medium brown; coxae I-IV white; trochantera I-IV brown; femora I-IV with proximal part white, distal part dark brown; tibiae I-IV with brown lateral stripes. Sternum densely covered with long setae.

Eyes. AME largest. Eye group width 0.59 of caput width. Diameters: AME 0.18; ALE 0.14; PME 0.16; PLE 0.16. Interspaces: AME-AME 0.04; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.12; ALE-PLE 0.04. MOQ: AME-PME 0.44; AME-AME 0.40; PME-PME 0.40. Clypeus 0.56 high.

Abdomen. Tracheal spiracle small, slit-like, with sclerotised cover.

Legs. Femora III, IV with a row of 5-6 stout dorsal spines at distal end; patellae III, IV with 1 irregular longitudinal row of stout spines prolaterally; metatarsi I, II with 2 rows of spines ventrally.

Male palp. (Fig. 4C–D) Cymbium with weak scopula and few spines apically; tip shorter than wide; retrolateral cymbial fold flat, 1/2 of cymbium length. LTA a broad, distally directed stalk, with long basoretrolateral spine; tip a long retrolateral spine. VTA short, relatively straight, with rounded tip, originating prolaterally. Tibia short; DTiA bifurcate. Female unknown.

DISTRIBUTION. Known only from the type locality in eastern Queensland (Fig. 10F).

Habronestes gumbardo sp. nov.
(Figs 7C-D, 10F)

ETYMOLOGY. A noun in apposition taken from the type locality.

MATERIAL. HOLOTYPE. Queensland: ♂, Gumbardo, site 1, 10638, 26°04'S, 144°45'E, Apr 2001, T. Beutel, pitfall (QM S63480). OTHER MATERIAL. Queensland: 3♂♂, same as holotype (QM S71624); 1♂, same (QM S63481).

DIAGNOSIS. This species resembles *H. boq* sp. nov. in abdominal pattern and the general shape of the male palp, but can be distinguished by the long , hook-shaped retrolateral tip of the retrolateral tegular apophysis (LTA) (Fig. 7C).

DESCRIPTION. *Male* (holotype). 5.76 long. Carapace 3.20 long, 2.40 wide, cl/cw 1.33, 1.36 high; caput 1.46 wide; sternum 1.40 long, 1.36 wide, sl/sw 1.03; abdomen 2.56 long, 1.92 wide.

Colour in alcohol. Carapace orange brown with dark margin, fovea and radiating stripes; sternum and chelicerae medium brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with 4 pairs of white spots, first and third larger, and one undulated spot in front of spinnerets; laterally with an elongate horizontal white stripe. Legs pale brown; coxae I-IV white; trochantera I-IV brown; femora and tibiae I-IV with brown lateral stripes.

Sternum. Densely covered with long setae.

Eyes. AME largest. Eye group width 0.62 of caput width. Diameters: AME 0.26; ALE 0.2; PME 0.2; PLE 0.2. Interspaces: AME-AME 0.02; AME-ALE 0.04; PME-PME 0.1; PME-PLE 0.12; ALE-PLE 0.04. MOQ: AME-PME 0.52; AME-AME 0.54; PME-PME 0.5. Clypeus 0.78 high.

Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with only 1 dorsal spine at distal end; patellae III, IV with 1 irregular

longitudinal row of stout spines prolaterally. Tibia and proximal part of metatarsus I with a band of short conical setae ventrally.

Male palp. (Fig. 7C–D) Cymbium with few spines apically, tip shorter than wide; retrolateral cymbial fold deep, 3/4 of cymbium length. LTA a long, retrolaterally directed stalk; tip with a long distally directed, retrolateral spine. VTA long, sickle-shaped, with rounded tip, originating basally. Tibia short; DTiA an undulated rim. Palpal patella with stout, conical, dorsal apophysis. Female unknown.

DISTRIBUTION. Known only from the type locality in central Queensland (Fig. 10F).

Habronestes hebronae Baehr, 2003
(Fig. 10A, figs 16, 29, 30, 33, 34, 48, 139)

Habronestes hebronae Baehr, 2003c: 352 (description of ♂, ♀). Holotype ♂, New South Wales, Pulletop, 33°00'S, 146°05'E, 24-28 Feb 1999, D. Driscoll, pitfall (QM S 50998) (examined).

MATERIAL. New South Wales: 1♂, Lower Murray-Darling Region, Belmore Station, 33°30'S, 141°10'E, 2 Apr 1999, M. LeBreton, pitfall (AM KS66605); 2♂♂, same, Mullingar Station, 33°20'S, 142°28'E, 12 Mar 1999, M. LeBreton, pitfall (AM KS66588, 66596); 8♂♂, same, Mulurulu Station, 33°20'S, 143°30'E, 19 Feb 1999, M. LeBreton, pitfall (AM KS66573-74,66577); 1♂, same, Popitah Station, 33°09'S, 141°41'E, 11 Oct 1999, M. LeBreton, pitfall (AM KS91481); 1♂, Pilliga region, 'road reserve', 30°10'S, 148°55'E, Feb 2001, I. Oliver, pitfall (AM KS80818); 2♂♂, Pulletop, 33°00'S, 146°05'E, 24-28 Feb 1999, D. Driscoll, pitfall (QM S51516); 1♂, Ronvue Stn, 17km SSE of Tottenham, 32o23'S, 147o26'E, 3 Mar 2000, D. Shelley, pitfall (AM KS73916); 1♀, Taleeban, 33°56'S, 146°25'E, 12-18 Oct 1999, D. Driscoll, pitfall (QM S53156); 1♂, Taleeban, grazed strip, no spinifex, 33°56'S, 146°25'E, 23-27 Feb 1999, D. Driscoll, pitfall (QM S50900). Queensland: 2♂♂, Baraeula Forest Station, Cypress Forest, 26°26'S, 150°30'E, 10-15 Oct 2004, G. Monteith, S. Wright, MV lamp (QM S68077); 13♂♂, Charleville, Merigol, mulga, 26°48'S, 145°49'E, Apr 2001, T. Beutel, pitfall (QM S63521-S63532); 1♂, Dotswood, 19°28'S, 146°27'E Feb 1999, Woinarski, pitfall (QM S71599); 1♂, East Woodmillar, 350m, vine scrub, 25°41'S, 151°36'E, J. Monteith, G. Thompson, pitfall (QM S51170); 1♂, Lake Broadwater, via Dalby, 27°21'S, 151°07'E, 25 Feb-27 Apr 1986, M. Bernie, pitfall (QM S47645); 1♂, same, 26 Mar-17 May. 1985, (QM S47681); 1♂, same, 27 Jan 2002, N. Platnick, B. Baehr, R. Raven, hand coll. (QM S72770); 1♂, Moranbah, 22°03'S, 148°04'E, 20 Dec 1997-26 Apr 1998, Monteith, pitfall (QM S47534); 1♂, Moranbah, 5km S, 240m, Gravel Ridge, 22°02'S, 148°03'E, 28 Feb-28 Mar 1995, G. Monteith, pitfall (QM ex S47532); 1♂, Mt Pollux SW base, Brigalow, 400m, 22°28'S, 147°52'E, 5-6 Mar 2006, G. Monteith, dung trap (QM S74281); 1♂, Mt Rose, via Taroom, 24°38'S, 150°57'E, 30 Mar 1997, D. Cook, hand coll (QM S47520); 2♂♂, Mundubbera, 23°35'S, 151°18'E, 28 Oct 1993, pitfall (QM S60646); 1♂, Wanoan, Rolane Station, 26°07'S, 149°57'E, 27-29 Oct 1979, A. Rozefeld (QM S3816).

DIAGNOSIS. This species resemble *H. boq* sp. nov. in colour pattern and the general shape of the male palp and female epigyne, but can be easily distinguished by tibia I with a band of conical thornlike spines ventrally and LTA with long needle-like retrolateral thorn.

DISTRIBUTION. New South Wales and eastern of Queensland (Fig. 10A, fig 139).

Habronestes hooperi sp. nov.
(Figs 1E, 6E–F, 10E)

ETYMOLOGY. The specific name is a patronym in honour of Dr John Hooper, the Head of Biodiversity and Geosciences Programs of the Queensland Museum, and Director Queensland Centre for Biodiversity, who supported the 'Name a Spider' project and encouraged me in my revisionary taxonomic work.

MATERIAL. HOLOTYPE. Queensland: ♂, Oak Wells, 600m, 10420, 25°46'S, 148°17'E, 15 Dec 2001-7 Feb 2002, G. Monteith, D. Cook, pitfall (QM S58666).

DIAGNOSIS. This species can be separated from all the others described here by the extremely small bulb of the male palp (Fig. 6E).

DESCRIPTION. *Male* (holotype). 5.76 long. Carapace 3.16 long, 2.12 wide, cl/cw 1.49, 1.12 high; caput 1.32 wide; sternum 1.40 long, 1.20 wide, sl/sw 1.17; abdomen 2.60 long, 1.80 wide.

Colour in alcohol. Carapace, sternum and chelicerae medium brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with 2-3 pairs of white spots and an elongate and undulate spot in front of spinnerets; laterally with 2 white spots, anterior small, posterior elongate; ventrally pale brown. Legs pale brown; coxae I-IV white; trochantera I-IV white; femora I-IV with proximal part white shading to dark brown distally.

Sternum. Densely covered with long setae.

Eyes. AME largest. Eye group width 0.61 of caput width. Diameters: AME 0.18; ALE 0.17; PME 0.16; PLE 0.17. Interspaces: AME-AME 0.06; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.10; ALE-PLE 0.04; MOQ: AME-PME 0.46;

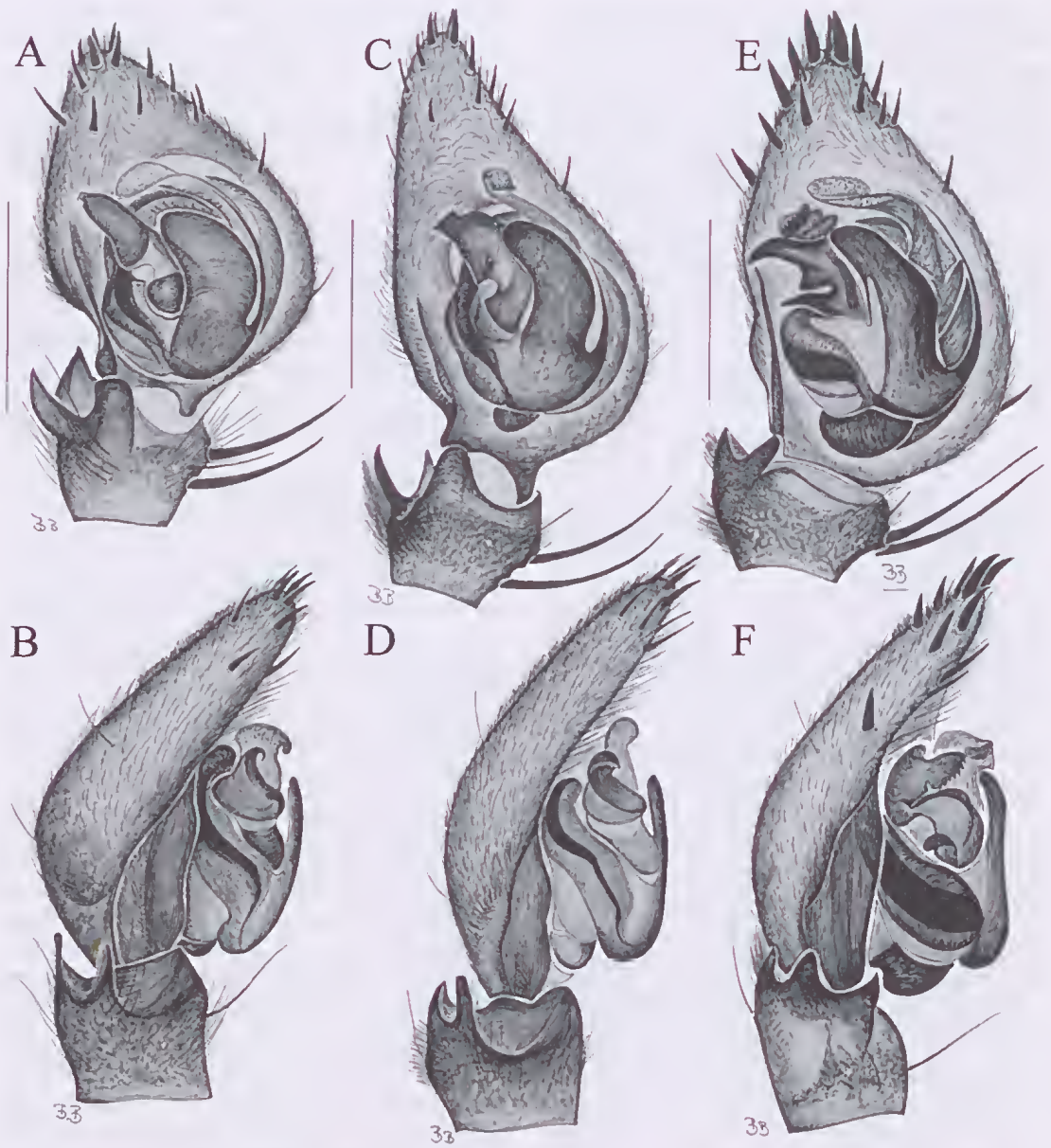

FIG. 5. *Habronestes* speeies, male palps, ventral view (top), lateral view (bottom). A-B, *H. diocesegrafton* sp. nov.; C-D, *H. ulrichi* sp. nov.; E-F, *H. archiei* sp. nov.

AME-AME 0.42; PME-PME 0.40. Clypeus 0.56 high.

Legs. Femora III, IV with a row of 5-6 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally; metatarsi I, II with 2 rows of spines ventrally.

Male palp. (Fig. 6E-F) Cymbium with long dorsal scopula and few spines apically; retrolateral fold flat, 1/3 of cymbium length. LTA a broad, distally directed stalk with long basoretrolateral spine; tip long and sharp. VTA long and slender, sickle-shaped, with rounded tip, originating basally. Tibia short; DTiA short, triangular. Female unknown.

DISTRIBUTION. Known only from the type loeality in south-eastern Queensland (Fig. 10E).

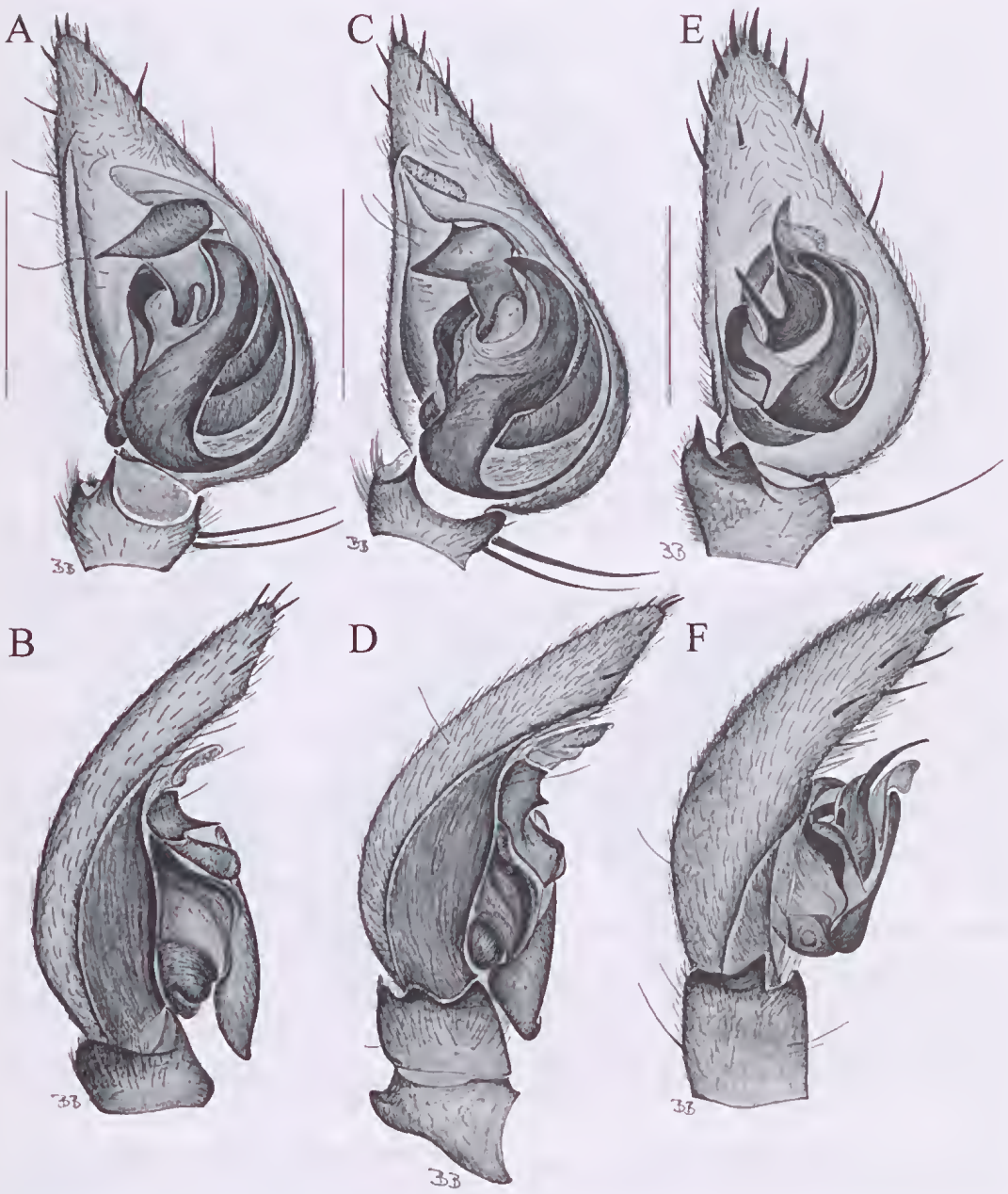

FIG. 6. *Habronestes* species, male palps, ventral view (top), lateral view (bottom). A-B, *H. dickmani* sp. nov.; C-D, *H. powelli* sp. nov.; E-F, *H. hooperi* sp. nov.

Habronestes jankae sp. nov.
(Figs 2C, 3E-F, 8C-D, 10B)

ETYMOLOGY. In honour of Janka Henke, the director of the German Austrian Travel Agency, who supported the 'Name a Spider' project.

MATERIAL. HOLOTYPE. Queensland: ♂, Wandoan, Rolane str., 26°07'S, 149°57'E, 28 Oct 1979, A. Rozefelds (QM S3844 HT). OTHER MATERIAL. Queensland: 1♂, Allies Creek, 5km N, 360m, 10408, 26°03'S, 151°06'E, 11 Dec 2001-4 Mar 2002, G. Monteith, D. Cook, pitfall (QM S58654); 1♀, Brigalow Res. Stn., 170m, 10017, 24°48'S, 149°47'E, 16 Dec

2000-28 Mar 2001, D. Cook, G. Monteith, pitfall (QM S72778). New South Wales: 1♀, Corowa, 13.5km NW, roadside, 35°54'S, 146°16'E, Nov 2000, D. Freudenberger, pitfall (AM KS 84404).

DIAGNOSIS. Males and females have not been collected together, but are matched on the basis of their identical abdominal colour pattern and their sternae which are densely covered with long setae. Males of this species resemble *H. gallowayi* sp. nov. in abdominal pattern and the general shape of the male palp but can be distinguished by the cymbium which is densely covered with long setae (Fig. 3E-F). Females can be clearly separated from all other known females of the *Habronestes macedonensis*-group by their globular spermatheeae (Fig. 8D).

DESCRIPTION. *Male* (holotype). 6.76 long. Carapace 3.36 long, 2.36 wide, cl/cw 1.42, 1.40 high; caput 1.22 wide; sternum 1.52 long, 1.28 wide, sl/sw 1.19; abdomen 3.40 long, 2.16 wide.

Colour in alcohol. Carapace orange brown, with dark fovea and dark bifurcate patches in front; sternum and chelicerae orange brown; endites and labium pale brown, distally white. Abdomen sepia brown, dorsally with 3 pairs of white spots and 1-2 spots in front of spinnerets; laterally with 2 white spots, anterior small, posterior elongate; ventrally pale brown. Legs pale brown; coxae I-IV white; trochantera I-IV pale, brown; femur I dark brown, II-IV with proximal part white, distal part dark brown; tibiae I-IV with brown lateral stripes (Fig. 2C).

Sternum. Densely covered with long setae.

Eyes. AME largest. Eye group width 0.66 of caput width. Diameters: AME 0.22; ALE 0.18; PME 0.18; PLE 0.18. Interspaces: AME-AME 0.02; AME-ALE 0.06; PME-PME 0.04; PME-PLE 0.14; ALE-PLE 0.06. MOQ: AME-PME 0.48; AME-AME 0.46; PME-PME 0.40. Clypeus 0.58 high.

Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with a row of 5-6 stout dorsal spines at distal end; patellae III, IV with 1 irregular longitudinal row of stout spines prolaterally. Metatarsus I with 2 irregular rows of small spines ventrally.

Male palp. (Fig. 3E-F). Cymbium densely covered with long setae, retrolateral cymbial fold flat, 1/3 of cymbium length. LTA a broad, distally directed stalk, tip folded with retrolateral spine. VTA sickle-shaped, with rounded tip, originating prolaterally. Tibia short, DTiA triangular.

Female. 7.88 long. Carapace 4.08 long, 2.56 wide, cl/cw 1.59, 1.68 high; caput 1.50 wide; sternum 1.68 long, 1.52 wide, sl/sw 1.11; abdomen 3.80 long, 2.88 wide.

Colour in alcohol. Carapace orange brown with dark fovea and dark bifurcate patches in front; sternum and chelicerae orange brown; endites and labium pale brown, distally white. Abdomen sepia brown, dorsally with 3 pairs of white spots and 1-2 spots in front of spinnerets; laterally with 2 white spots, anterior small, posterior elongate; ventrally pale brown. Legs pale brown; coxae I-IV white; trochantera I-IV white; femora I-IV with proximal part white, distal part pale brown.

Sternum. Densely covered with long setae.

Eyes. AME largest. Eye group width 0.72 of caput width. Diameters: AME 0.28; ALE 0.20; PME 0.20; PLE 0.20. Interspaces: AME-AME 0.04; AME-ALE 0.04; PME-PME 0.18; PME-PLE 0.12; ALE-PLE 0.04. MOQ: AME-PME 0.58; AME-AME 0.6; PME-PME 0.58. Clypeus 0.64 high.

Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with a row of 5-6 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally.

Epigyne. (Fig. 8C-D) With broadly oval copulatory openings, extremely short copulatory ducts and widely separated, globular spermathecae.

DISTRIBUTION. The female is from the southern border of New South Wales and the males from south-eastern of Queensland (Fig. 10B).

Habronestes macedonensis (Hogg, 1900)
(figs 35, 36, 37, 40, 41, 46, 139)

Storena macedonensis Hogg, 1900: 2, 97, 98, pl. 14, fig. 4 (description of ♂); Rainbow, 1911: 150 (description of ♂). Holotype BMNH 1907.2.24.38 Victoria, Macedon, examined by Joqué, 1995b.

Habronestes macedonensis Hogg. Joqué, 1995: 145, fig. 3c-d (description male); Baehr, 2003e: 351, figs 35-37, 40, 41 (description of ♂, ♀).

REMARKS. The male of *Habronestes macedonensis* was first described by Hogg, 1900 as *Storena macedonensis*. Joqué (1995) reexamined the holotype and placed the species in *Habronestes* because of the palp structure.

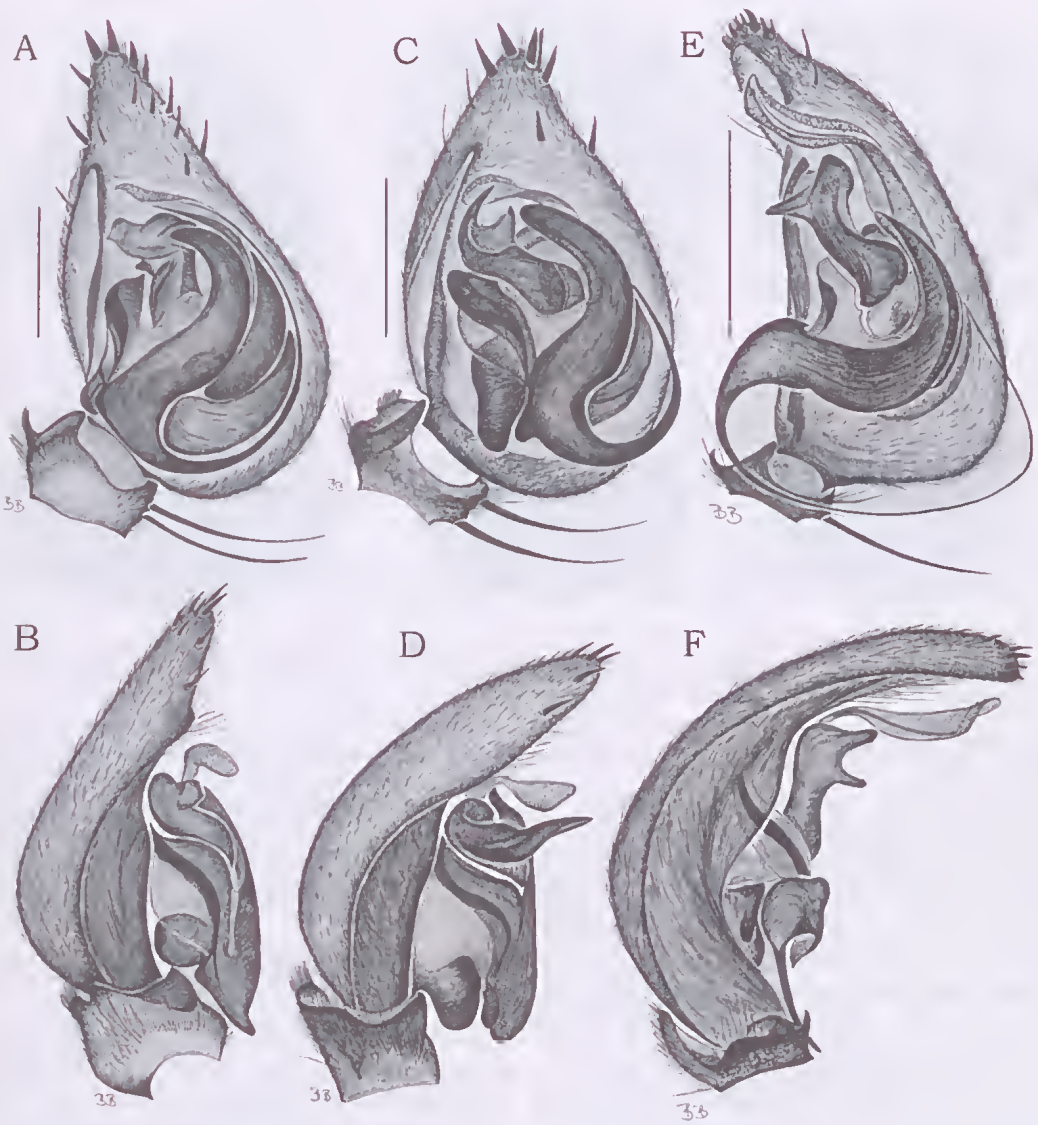

FIG. 7. *Habronestes* species, male palps, ventral view (top), lateral view (bottom). A-B, *H. boq* sp. nov.; C-D, *H. gumbardo* sp. nov.; E-F, *H. clausoni* sp. nov.

Baehr (2003c) provided a detailed redescription of the species.

DIAGNOSIS. Males of *H. macedonensis* can be easily separated from all other species by the fan-shaped retrolateral tegular apophysis (LTA) that is covered with small spicules (figs 40, 41) and females by their epigyne which has a w-shaped scapus (figs 35, 36).

DISTRIBUTION. Victoria, New South Wales and Tasmania (fig. 139).

Habronestes powelli sp. nov.
(Figs 2A,G,I 6C-D, 9C-D, 10E)

ETYMOLOGY. In honour of Howard Powell, the director of qlab Brisbane, who installed the LEICA MZ16 and supported the spider taxonomy from the equipment side.

MATERIAL. HOLOTYPE. New South Wales: ♂, Lower Murray-Darling Region, Garston Station, 33°43'S, 141°55'E, 24–28 Jan 2000, M. LeBreton, pitfall (AM KS91546). ALLOTYPE. New South Wales: ♀, Lower Murray-Darling Region, Willotia

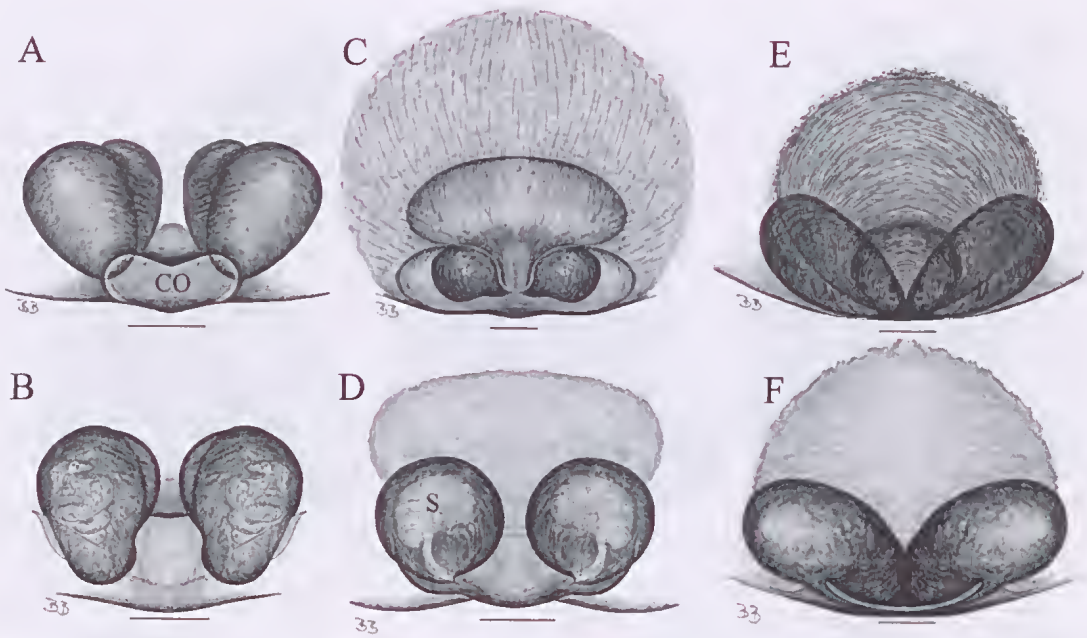

FIG. 8. *Habronestes* species, epigynes, ventral view (top), dorsal view (bottom). A-B, *H. ungari* Baehr; C-D, *H. jankae* sp. nov.; E-F, *H. drummond* sp. nov.

Station, 32°53'S, 142°14'E, 14 –18 Feb 2000, M. LeBreton, pitfall (AM KS91572).

DIAGNOSIS. This species resembles *H. dickmani* sp. nov. in body shape and the general structure of the male palp but can be distinguished by the distinctive, stout, conical, dorsal apophysis on the palpal femur. Males and females can be separated from *H. dickmani* sp. nov. by having a broader cephalic area and two dark lateral bands on the carapace that unite just behind the fovea and reach posterior margin of the carapace (Fig. 2G, I). The abdominal patterns of *H. powelli* and some specimens of *H. dickmani* differ from those of all other members of the *H. macedonensis*-group by having dark chevrons on a pale background.

DESCRIPTION. *Male* (holotype). 4.40 long. Carapace 2.12 long, 1.68 wide, cl/cw 1.26, 1.00 high; caput 1.02 wide; sternum 1.00 long, 0.96 wide, sl/sw 1.04; abdomen 2.28 long, 1.72 wide.

Colour in alcohol. Carapace yellow with dark cephalic area, and two dark lateral bands that unite just behind fovea and reach posterior margin of carapace; sternum and chelicerae yellow; endites and labium yellow, distally white. Abdomen pale, dorsally with brown chevrons, and light brown ring around spinnerets and tracheal spiracle. Legs pale.

Eyes. AME largest. Eye group width 0.67 of caput width. Diameters: AME 0.21; ALE 0.14; PME 0.14; PLE 0.14. Interspaces: AME-AME 0.02; AME-ALE 0.04; PME-PME 0.12; PME-PLE 0.10; ALE-PLE 0.04. MOQ: AME-PME 0.40; AME-AME 0.44; PME-PME 0.40. Clypeus 0.50 high.

Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with a row of 3-4 stout dorsal spines at distal end; patellae III, IV with 1 irregular longitudinal row of stout spines prolaterally. Tibia I with a band of short conical setae ventrally.

Male palp (Fig. 6C-D). Cymbium with few spines apically, retrolateral fold deep, 3/4 of cymbium length. LTA a cylindrical, distally directed stalk, tip scooped, with tiny, distal thorn. VTA long, sickle-shaped, with sharp tip, originating basoretrolaterally. Tibia short; DTiA slightly bifurcate. Palpal patella with stout, conical, dorsal apophysis.

Female. (allotype) 4.84 long. Carapace 2.40 long, 1.72 wide, cl/cw 1.4, 0.96 high; sternum 1.16 long, 1.08 wide, sl/sw 1.07; abdomen 2.44 long, 1.84 wide.

Colour in alcohol. same as male.

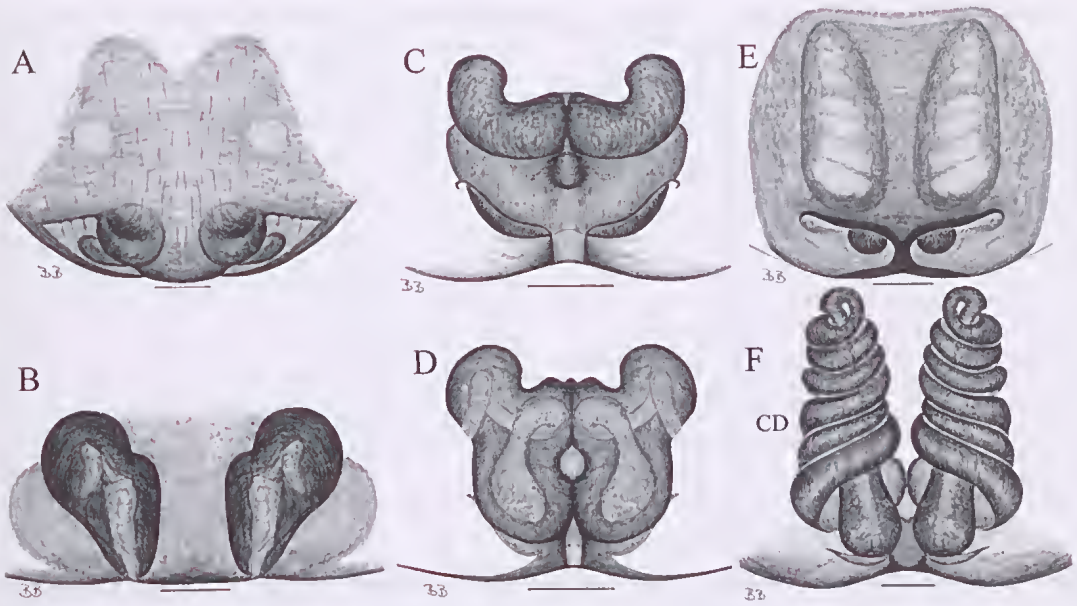

FIG. 9. *Habronestes* species, epigynes, ventral view (top), dorsal view (bottom). A-B, *H. boq* sp. nov; C-D, *H. powelli* sp. nov.; E-F, *H. clausoni* sp. nov.

Eyes. AME largest. Caput 1.22 wide. Eye group width 0.62 of caput width. Diameters: AME 0.24; ALE 0.14; PME 0.14; PLE 0.16. Interspaces: AME-AME 0.02; AME-ALE 0.04; PME-PME 0.16; PME-PLE 0.12; ALE-PLE 0.04. MOQ: AME-PME 0.44; AME-AME 0.5; PME-PME 0.44. Clypeus 0.54 high.

Legs. Same as male but Tibia 1 without a band of short conical setae ventrally. Female palpal tibia and tarsus with a pro- and retrolateral row of long, slightly bent setae.

Epigyne. (Fig. 9C-D) With paired, slit-like copulatory openings. Copulatory ducts twisted, ending in globular, contiguous spermatheeae.

DISTRIBUTION. Far western New South Wales (Fig. 10E).

Habronestes rawlinsonae Baehr, 2003
(Fig. 10A, figs 15, 27, 28, 31, 32, 50, 139)

Habronestes rawlinsonae Baehr, 2003c: 353 (description of ♂, ♀). Holotype ♂, New South Wales, Gubbata, 33°34'S, 146°34'E, 24-28 Feb 1999, D. Driscoll, pitfall (QM S 51007) (examined).

MATERIAL. New South Wales: 3♂♂, Taleeban, 33°55'S, 146°27'E, 23-27 Feb 1999, D. Driscoll, pitfall (QM S50845); 4♂♂, same (QM S51626); 2♂, same (QM S51596); 1♂, same, 33°57'S, 146°37'E (QM S51531); Queensland, 2♂♂, Gumbardo, 26°04'S, 144°45'E, Apr 2001, T. Beutel (QM S63439, S63478).

DIAGNOSIS. This species resembles *H. boq* sp. nov. in colour pattern, general shape of male palp and female epigyne but can be easily distinguished by the horseshoe-shaped retrolateral tegular apophysis.

DISTRIBUTION. New South Wales, south western Queensland (Fig. 10A, fig. 139).

Habronestes tillmani sp. nov.
(Figs 1F, 4E-F, 10C)

ETYMOLOGY. In honour of Tillman Baehr, my godson who is very interested in natural history.

MATERIAL. HOLOTYPE. New South Wales: ♂, Gordon, 9 Nov 1981, 33°45'S, 151°10'E, C. Horseman (AM KS8553). OTHER MATERIAL. Queensland: 1♂, Weipa, 12°40'S, 143°00'E, 20 Mar-20 Apr 1994, P. Zborowski, flight intersept trap (QM S72766).

DIAGNOSIS. This species resembles *H. ulrichi* sp. nov. in dorsal abdominal pattern in having just a single pair of white spots dorsally and a single spot in front of the spinnerets. It can be distinguished by the male palp which has the tip of retrolateral tegular apophysis (LTA) with two long apophyses (Fig. 4E,F).

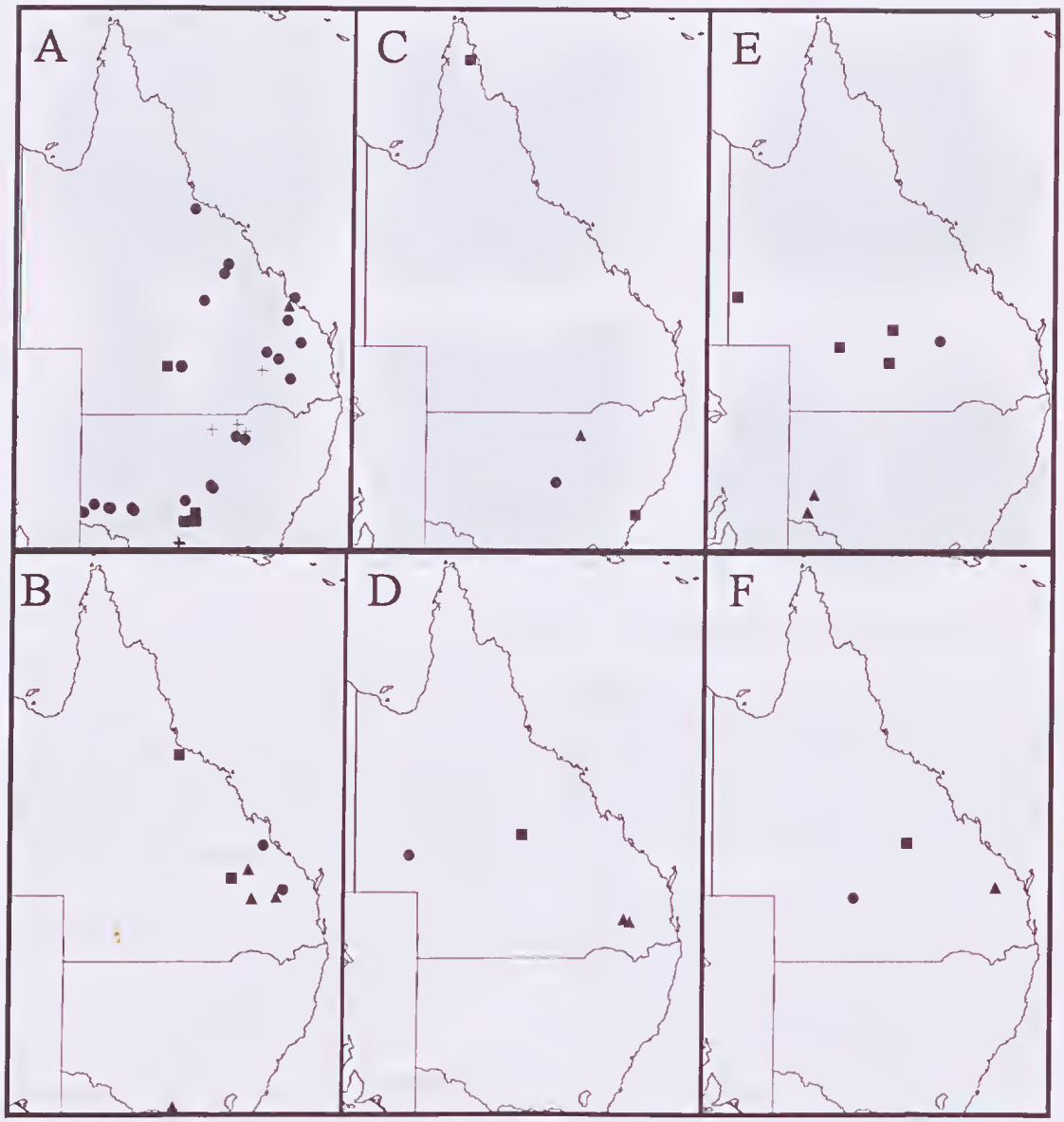

FIG. 10. Distribution records for *Habronestes* species. Only new records for previously described species are presented.
A, • *H. hebronae* Baehr; ■ *H. rawlinsonae* Baehr; ▲ *H. weelahensis* Bachr; + *H. ingari* Baehr.
B, • *H. gallowayi* sp. nov.; ■ *H. boq* sp. nov.; ▲ *H. jankae* sp. nov.;
C, • *H. ulrichi* sp. nov.; ■ *H. tillmani* sp. nov.; ▲ *H. diocesegrafton* sp. nov.;
D, • *H. clausoni* sp. nov.; ■ *H. archiei* sp. nov.; ▲ *H. braemar* sp. nov.;
E, • *H. hooperi* sp. nov.; ■ *H. dickmani* sp. nov.; ▲ *H. powelli* sp. nov.;
F, • *H. gumbardo* sp. nov.; ■ *H. drummond* sp. nov.; ▲ *H. gayndah* sp. nov.

DESCRIPTION. *Male* (holotype). 6.88 long. Carapace 3.36 long, 2.24 wide, cl/cw 1.50, 1.52 high; caput 1.34 wide; sternum 1.44 long, 1.32 wide, sl/sw 1.09; abdomen 3.52 long, 2.24 wide. *Colour in alcohol.* Carapace and sternum orange brown; chelicerae medium brown; endites and labium pale brown, distally white. Abdomen sepia brown, dorsally with a pair of white spots

and a spot in front of spinnerets; laterally with a white patch; ventrally pale brown. Legs pale brown; coxae I-IV white; trochantera I-IV brown; femora I with proximal and distal parts brown, middle white, II-IV with proximal part white, distal part dark brown; tibiae I-IV with brown lateral stripes.

Sternum. Densely covered with long setae.

Eyes. AME largest. Eye group width 0.69 of caput width. Diameters: AME 0.28; ALE 0.18; PME 0.2; PLE 0.18. Interspaces: AME-AME 0.04; AME-ALE 0.04; PME-PME 0.12; PME-PLE 0.12; ALE-PLE 0.04. MOQ: AME-PME 0.54; AME-AME 0.60; PME-PME 0.52. Clypeus 0.60 high.

Abdomen. Tracheal spiracle small, slit-like, with a tiny pit.

Legs. Femora III, IV with a row of 3-4 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally; distal part of tibia and metatarsus I with a band of short conical setae ventrally.

Male palp. (Fig. 4E–F) Cymbium with few spines apically; tip shorter than wide; retrolateral cymbial fold flat, 1/2 of cymbium length. LTA a distally directed stalk; tip with two long apophyses, distal one fan-shaped. VTA long, sickle-shaped, originating prolaterally. Tibia globose; DTiA bifurcate.

Female unknown.

DISTRIBUTION. Coastal New South Wales and Queensland (Fig. 10C).

Habronestes ulrichi sp. nov.
(Figs 2D, 5C–D, 10C)

ETYMOLOGY. For Ulrich Baehr, my son, in honour of his 21st birthday, and who is very interested in natural history.

MATERIAL. HOLOTYPE. New South Wales: ♂, Tottenham 17km SSE, 'Ronvue' Station, 32°14'S, 147°18'E, 27 Feb–3 Mar 2000, D. Shelley, pitfall (AM KS97274). OTHER MATERIAL. New South Wales: 1♂, same as holotype (AM KS73907).

DIAGNOSIS. This species resembles *H. diocesegrafton* sp. nov. in the general shape of the male palp, but can be distinguished by the broader tip of the retrolateral tegular apophysis (LTA) (Fig. 5C,D). In addition, *H. ulrichi* differs in the abdominal pattern which has a single pair of white spots dorsally and a single spot in front of the spinnerets.

DESCRIPTION. *Male* (holotype). 5.92 long. Carapace 3.44 long, 2.40 wide, cl/cw 1.43, 1.24 high; caput 1.54 wide; sternum 1.60 long, 1.36 wide, sl/sw 1.18; abdomen 2.48 long, 2.12 wide.

Colour in alcohol. Carapace, sternum and chelicerae sepia brown; endites and labium medium brown, distally white. Abdomen sepia brown, dorsally with a pair of white spots and a spot in front of spinnerets. Legs medium brown; coxae I-IV white; trochantera I-IV brown; femur I dark brown, II-IV with proximal part white, distal part dark brown; tibiae I-IV with brown lateral stripes. Sternum densely covered with long setae.

Eyes. AME largest. Eye group width 0.65 of caput width. Diameters: AME 0.24; ALE 0.2; PME 0.22; PLE 0.20. Interspaces: AME-AME 0.04; AME-ALE 0.04; PME-PME 0.08; PME-PLE 0.12; ALE-PLE 0.04. MOQ: AME-PME 0.54; AME-AME 0.52; PME-PME 0.52. Clypeus 0.66 high.

Abdomen. With weak dorsal scutum. Tracheal spiracle slit-like, with broad sclerotised cover.

Legs. Femora III, IV with a row of 5-6 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally.

Male palp (Fig. 5C-D). Cymbium with weak dorsal apical scopula and few spines apically; retrolateral cymbial fold flat, 1/3 of cymbium length. LTA a broad, distally directed stalk, tip straight. VTA sickle-shaped, with rounded tip, originating prolaterally. DTiA bifurcate.

Female unknown.

DISTRIBUTION. Central New South Wales (Fig. 10C).

Habronestes ungari Baehr, 2003
(Figs 8A-B, 10A, figs 38, 44, 45, 49, 139)

Habronestes ungari Baehr, 2003c: 354 (description of ♂). Holotype ♂, New South Wales, Ungarie SF, 33°39'S, 147°40'E, 25 Mar 1996 D. Smith, R. Harris (AM KS 83934) (examined).

MATERIAL. New South Wales: 1♀, Narran Plains Rd, 3.8km N of Narran Lake jctn. (DRRPT137/05), 29°41'S, 147°20'E, 15 Dec 1999, F. Christie, P. Flemons & M. Elliott, pitfall (AM KS73756); 1♂, Cameron Lane, 4.6km W of Burren-Pocataroo Rd jctn., 29°48'S, 148°58'E, 14 Dec 1998, L. Wilkie, pitfall (AM KS73751); 2♂♂, Coleambally Irrigation Area, 34°56'S, 145°46'E, 28 Apr 1999, L. Wilkie, pitfall (AM KS67599, AM KS67615); 2♂♂, same,

35°02'S, 145°49'E, 14 Dec 1998, L. Wilkie, pitfall (AM KS68945, AM KS68960); 1♂, Pilliga region, 'Plain View', 30°10'S, 148°57'E, Feb 2001, I. Oliver, pitfall (AM KS80819); 1♂, Pilliga region, 'Rossmore Holdings' 30°04'S, 148°57'E, Feb 2001, I. Oliver, pitfall (AM KS80820). Queensland: 1♂, Yuleba State Forest, site 4, 270m, 26°58'S, 149°44'E, 9-10 Mar 2002, G. Monteith, D. Cook, dung trap (QM S58628).

DIAGNOSIS. This species resembles *H. gayndah* sp. nov. in abdominal pattern and the general shape of the male palp but can be distinguished by the extremely short VTA. Baehr, 2003c described only the male of *H. unigari*. The newly discovered female is decribed below.

DESCRIPTION. *Female.* (AM KS73756) 8.04 long. Carapace 3.64 long, 2.52 wide, el/cw 1.75, 1.44 high; caput 1.76 wide; sternum 1.52 long, 1.36 wide, sl/sw 1.12; abdomen 4.40 long, 3.00 wide.

Colour in alcohol. Carapace pale brown with dark fovea and dark radiating stripes; sternum and chelicerae pale brown; endites and labium pale brown, distally white. Abdomen sepia brown, dorsally with 3 pairs of white spots and 1-2 spots in front of spinnerets (fig. 38); laterally with 2 elongate white spots, anterior larger. Legs pale brown, with darker brown lateral stripes; coxae I-IV white; trochantera I-IV white; femora I-IV with proximal part white, distal part dark brown.

Eyes. AME largest. Eye group width 0.69 of caput width. Diameters: AME 0.32; ALE 0.24; PME 0.24; PLE 0.24. Interspaces: AME-AME 0.06; AME-ALE 0.04; PME-PME 0.16; PME-PLE 0.16; ALE-PLE 0.04. MOQ: AME-PME 0.60; AME-AME 0.70; PME-PME 0.64. Clypeus 0.64 high; chilum undivided.

Abdomen. Tracheal spiracle small, slit-like, covered with small stout spines.

Legs. Femora III, IV with a row of 3-4 stout dorsal spines at distal end; patellae III, IV with 2 longitudinal rows of stout spines prolaterally.

Epigyne. (Fig. 8A, B) With broadly oval copulatory opening and arched anterior margin. Copulatory ducts extremely short, spermathecae widely separated, inverted pear-shaped.

DISTRIBUTION. New South Wales and southern Queensland (Fig. 10A, fig. 139).

Habronestes weelahensis Baehr, 2003
(Fig. 10A, figs 39, 42, 43, 47, 139)

Habronestes weelahensis Baehr, 2003c: 355 (description of ♂). Holotype ♂, New South Wales, Weelah SF, Callitris forest, 33°21'S, 147°15'E, 25 Mar 1996, D. Smith, R. Harris, pitfall (AM KS 560900) (examined).

MATERIAL. Queensland: 1♂, Wycheproof, 23°59'S, 151°01'E, July 1998, pitfall (QM S72765).

DIAGNOSIS. Males of this species resemble *H. clausoni* sp. nov. in the general shape of the palp but can be distinguished by the much shorter retrolateral cymbial fold. In addition *H. weelahensis* can be distinguished by metatarsus I having one row of about 15 small spines ventrally.

DISTRIBUTION. New South Wales and coastal Queensland (Fig. 10A, fig. 139).

DISCUSSION

Zodariids are ground dwelling spiders that are not known to disperse aerially. They are often endemic to small areas, sometimes only to small patches of rainforest (e.g. species of *Tropasteron* Baehr, 2003b). Their low vagility makes ant spiders important for biogeographic studies.

The yellow-spotted ground spiders of the genus *Habronestes* belong to one of the most diverse ant spider genera in Australia. Fifty species, including those in this paper, have been described to date, but about 80 species are still undescribed. Although the genus *Habronestes* is not fully revised, there are already some biogeographical patterns evident. Only one species of the *macedonensis*-group is known from Tasmania (*H. macedonensis* itself) with 11 species now recorded from New South Wales and 15 from Queensland. This indicates that the *macedonensis*-group probably is most diverse and mainly distributed in the tropical and subtropical parts of Australia. Further studies will provide more detailed information about the relationships between the species, species groups and their distribution patterns.

ACKNOWLEDGEMENTS

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ASTERIACITES IN THE LOWER CRETACEOUS OF QUEENSLAND. *Memoirs of the Queensland Museum 52(2): 88.* Noteworthy specimens of the distinctive trace fossil Asteriacites were recovered from the eastern margins of the Carpentaria Basin (Great Artesian Superbasin). These specimens are associated with a diverse ichnological assemblage including Planolites and Rosellia. The trace fossils assemblage is preserved in creek bank outcrops mapped as the Gilbert River Formation. The coarse sandstones displays ripple cross lamination, ubiquitous bedding-parallel bioturbation suggesting a shallow marine moderate energy environment.

Stratigraphic relationships in the general area (AGSO, 1997) indicate that the sequence present at the site is within ten metres above basement consisting of Mid Palaeozoic volcanics of the Scardons Volcanic Group and Palaeozoic granitoids.

The age of the Gilbert River Formation is poorly constrained, with most sources citing a Jurassic-Cretaceous (Aptian) age for the unit. Burger (1986) indicated a range of *Cicatricosporosis australiensis* to *Foraminisporosis. symmetricus* spore pollen Zones. These units may however be equivalent in age to elements of the Coffin Hill Sandstone at Croydon, which is Aptian (Foram. assymetricus Zone).

Large monasterid sea-star fossils are known from scattered occurrences in the Late Aptian Doncaster Formation (e.g. Kronosaurus Korner, Richmond KKM 180) and from the Albian Allaru and Mackunda Formations (QM collections).

Asteriacites is quite common at the locality. The present specimens(QMF42629, QMF49524–6) are preserved in marked hyporelief and are up to 132mm wide across the widest spaced arms, with a central raised area of 30mm wide. The grain size limits detail of any of the oral disc or arms. These specimens indicate abundance of nearshore sea stars in the Cretaceous and point to the high diversity of undescribed ichnotaxa in the Great Artesian Basin.

Asteriacites is a common ichnogenus, preserved throughout the Palaeozoic to recent (Hanzschell, 1975) and Cretaceous examples have been recently described by Bell (2005).

Acknowledgements

Ian Sobbe, Mark Saul and Paul Tierney are thanked for collection of the figured specimens.

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Alex G. Cook, Queensland Museum, PO Box 3300, South Brisbane 4101, alex.cook@qm.qld.gov.au; 5 January 2007.

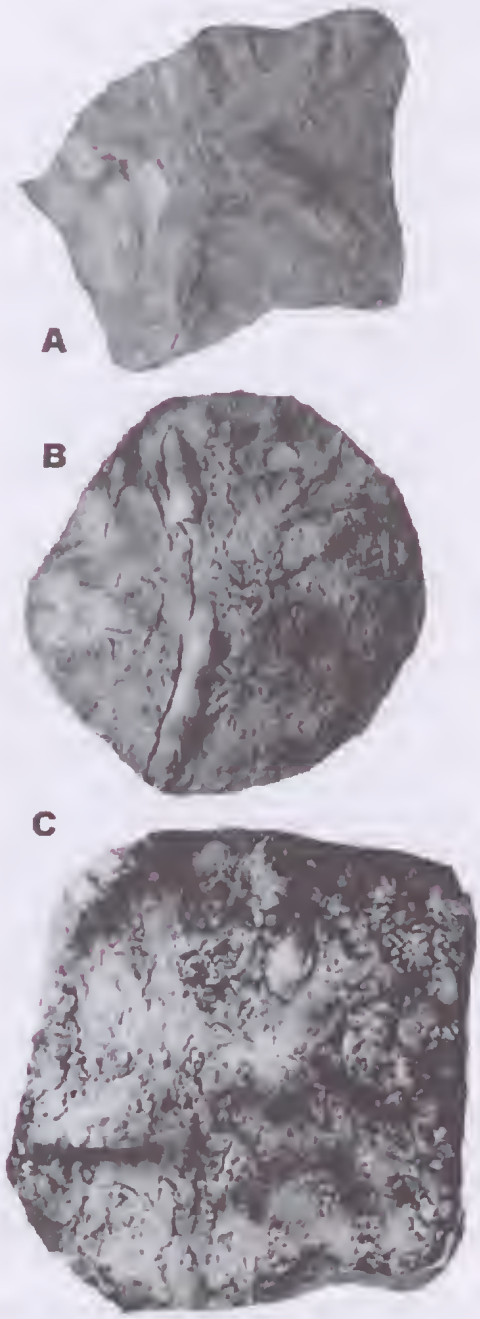

FIG. 1. *Asteriacites* isp. A.QMF42629 x0.6. B. QMF49525 x 0.4 C, QMF49526 x 0.7.

A NEW PONTONIINE SHRIMP FROM THE GREAT BARRIER REEF (CRUSTACEA. DECAPODA. PALAEMONIDAE)

A. J. BRUCE

Bruce, A.J. 2008 04 30: A new pontoniine shrimp from the Great Barrier Reef (Crustacea. Decapoda. Palaemonidae). *Memoirs of the Queensland Museum* **52**(2): 89-98. Brisbane. ISSN 0079-8835.

Periclimenes kallisto sp. nov., a pontoniine shrimp new to the Australian fauna, is described from Keeper and Swains Reefs, at the central region and southeastern end of the Great Barrier Reef. The specimens were found in association with unidentified antipatharian hosts at depths of 38 and 10 metres. *Periclimenes brocketti* Borradaile, 1915, is formally synonymised with *P. affinis* (Zehntner, 1902). ❑ *Periclimenes kallisto, new species, Pontoniinae, Great Barrier Reef, antipatharian associate, Australia.*

A. J. Bruce, Queensland Museum, PO Box 3300, South Brisbane, Qld 4101, (Email abruce@broad.net.au); 17 September 2006.

In 1978, the R.V. *Kallisto*, of the Russian Academy of Sciences Far East Science Center, Vladivostok, visited the Great Barrier Reef. During this cruise the Heron Island Research Station (HIRS) on the southern end of the Great Barrier Reef was visited and through the kindness of the Cruise Leader, Dr Boris V. Preobrazhensky, staff at the HIRS were able to participate in the subsequent leg of the cruise. The specimens upon which this report is based were collected in SCUBA activities whilst cruising. Specimens are deposited in the collections of the Queensland Museum, Natural History Museum-Naturalis, Leiden and Muséum National d'Histoire Naturelle, Paris.

ABBREVIATIONS. CL = postorbital carapace length; QM = Queensland Museum, Brisbane; MNHN = Muséum National d'Histoire Naturelle, Paris; RMNH = Natural History Museum-Naturalis, Leiden.

TAXONOMY

Crustacea Decapoda
Family Palaemonidae Rafinesque, 1815
Subfamily Pontoniinae Kingsley, 1879

Periclimenes Costa, 1844

Periclimenes kallisto sp. nov.
(Figs 1–6)

MATERIAL. HOLOTYPE, QMW28066, ovig. female, R.V. *Kallisto,* Keeper Reef, Queensland, 18°44'S, 147°16'E, 38m, D. Fisk, 30 June 1978.

PARATYPES. QMW28067, male allotype, RMNH D51733 male, ovig. female; MNHN Na16344, male, ovig. female, QMW 28068, 51 (incl.16 ovig. females), all with same data as holotype; QMW28069, 46 (incl. 12 ovig. females, R.V. *Kallisto,* Swains Reef, 21°30'S 152°00'E, Queensland, 10m, D. Fisk, 26 June 1978.

DIAGNOSIS. Rostral dentition.7–9/0–2 (ovig. female), posterior tooth frequently epigastric, straight, reaching to or beyond distal segment of antennular peduncle; inferior orbital angle without ventral flange; cornea globular, not produced. fourth thoracic sternite with transverse ridge with median notch, first pereiopod with simple fingers, cutting edges entire, carpus subequal to palm, second pereiopod chelae unequal, dissimilar, smooth, carpus and merus unarmed, fingers of major second pereiopod feebly dentate proximally, without distinct distal diastema, fingers of minor second pereiopod unarmed; third pereiopod slender, propod spinulate, spines slender, acute, dactyl slender, simple, unguis long, slender.

DESCRIPTION. A slenderly built *Periclimenes* (Fig. 1) of subcylindrical body form, body smooth, glabrous.

Rostrum. (Fig. 4A) Straight, horizontal, about 0.9 of CL, reaching from middle of distal segment of antennular peduncle to well beyond anterior margin of distal segment, with low dorsal carina, lateral carinae feebly developed, ventral carina obsolete, dorsal margin with 6–8 acute teeth, evenly spaced, first tooth posterior to orbital margin (with additional minute preterminal distal tooth (Fig. 6A) in one specimen), with sparse short interdental setae, ventral margin with single small acute tooth distally, ventral margin straight with median plumose setae. Male rostrum (Fig. 5A) similar to female.

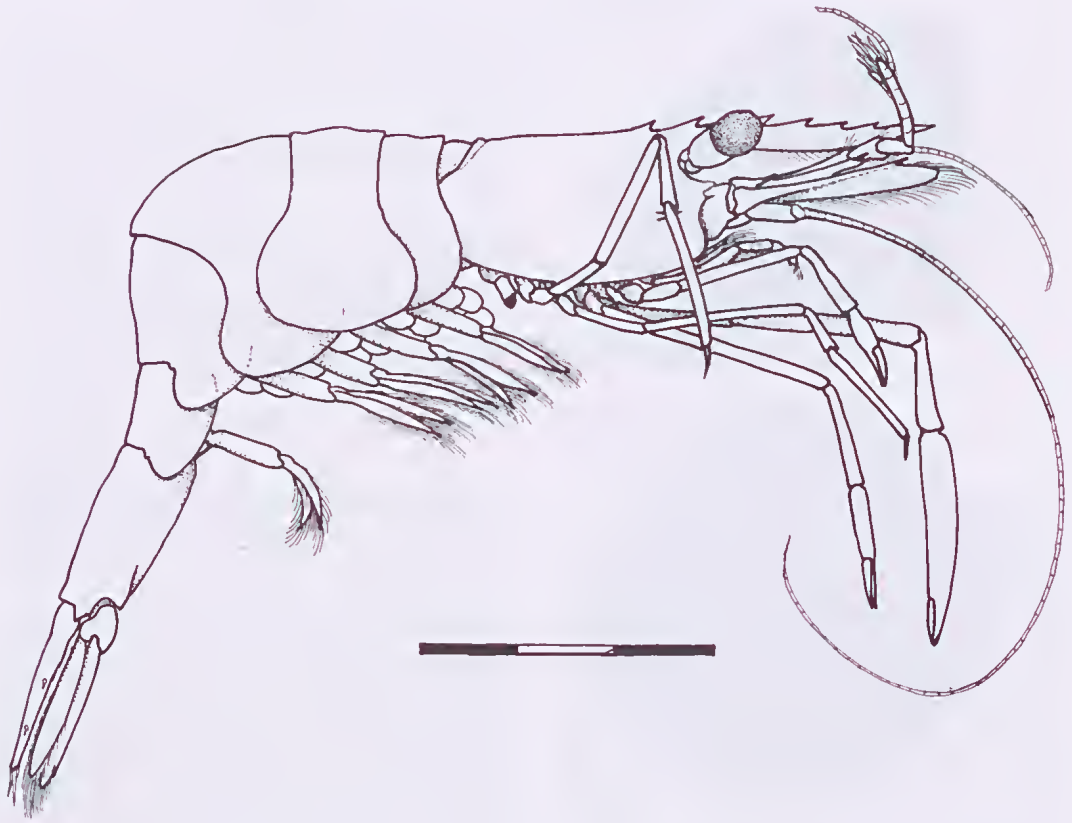

FIG. 1. *Periclimenes kallisto* sp. nov., ovig. female holotype, QMW28066, Swain Reefs. Scale bar in millimeters.

Carapace. (Fig. 2AB) with epigastric spine at about 0.2–0.3 of CL, generally posterior to level of hepatic spine, usually separated from first dorsal rostral tooth by distinctly larger interval than between first and second rostral teeth, without supraorbital spine or postorbital ridge, inferior orbital angle (Fig. 2C) produced, acute, without ventral flange, antennal spine slender, marginal, exceeding inferior orbital angle, hepatic spine similar to antennal, anterolateral angle rounded, not produced.

Abdomen. Third tergite not posteriorly produced, posterior margin entire, about 0.75 of CL, sixth segment 2.2 times longer than deep, 1.6 times fifth segment length, posterolateral angle angular, acute, posteroventral angle slightly produced, blunt, pleura of first three segments broadly rounded, fifth and sixth (Fig. 2D) posteriorly produced, rounded.

Telson. About 0.9 of CL (Fig. 2H), 3.0 times longer than anterior width, lateral margins posteriorly convergent, anterior third feebly concave, posterior two thirds straight, with two pairs of small dorsal spines, about 0.04 of telson length at 0.55 and 0.75 of telson length, posterior margin (Fig 3H) about 0.28 of anterior margin width, angular, central portion slightly produced, without acute median point, lateral spines small, subequal to dorsal spines, intermediate spines long, slender, about 0.2 of telson length, submedian spines shorter, robust, densely setose, about 0.4 of intermediate spine length.

Antennule. Normal form (Fig. 2E), proximal segment about 2.0 times longer than central width, tapering slightly distally, median margin straight, setose, with small acute ventromedial tooth at about 0.4 of length, lateral margin feebly convex, sparsely setose, anterolateral margin (Fig. 3G) produced with small rounded medial lobe and acute lateral tooth, distinctly exceeding medial lobe, stylocerite slender, acute, reaching to about 0.5 of segment length, proximal lateral margin with plumose setae, statocyst normally

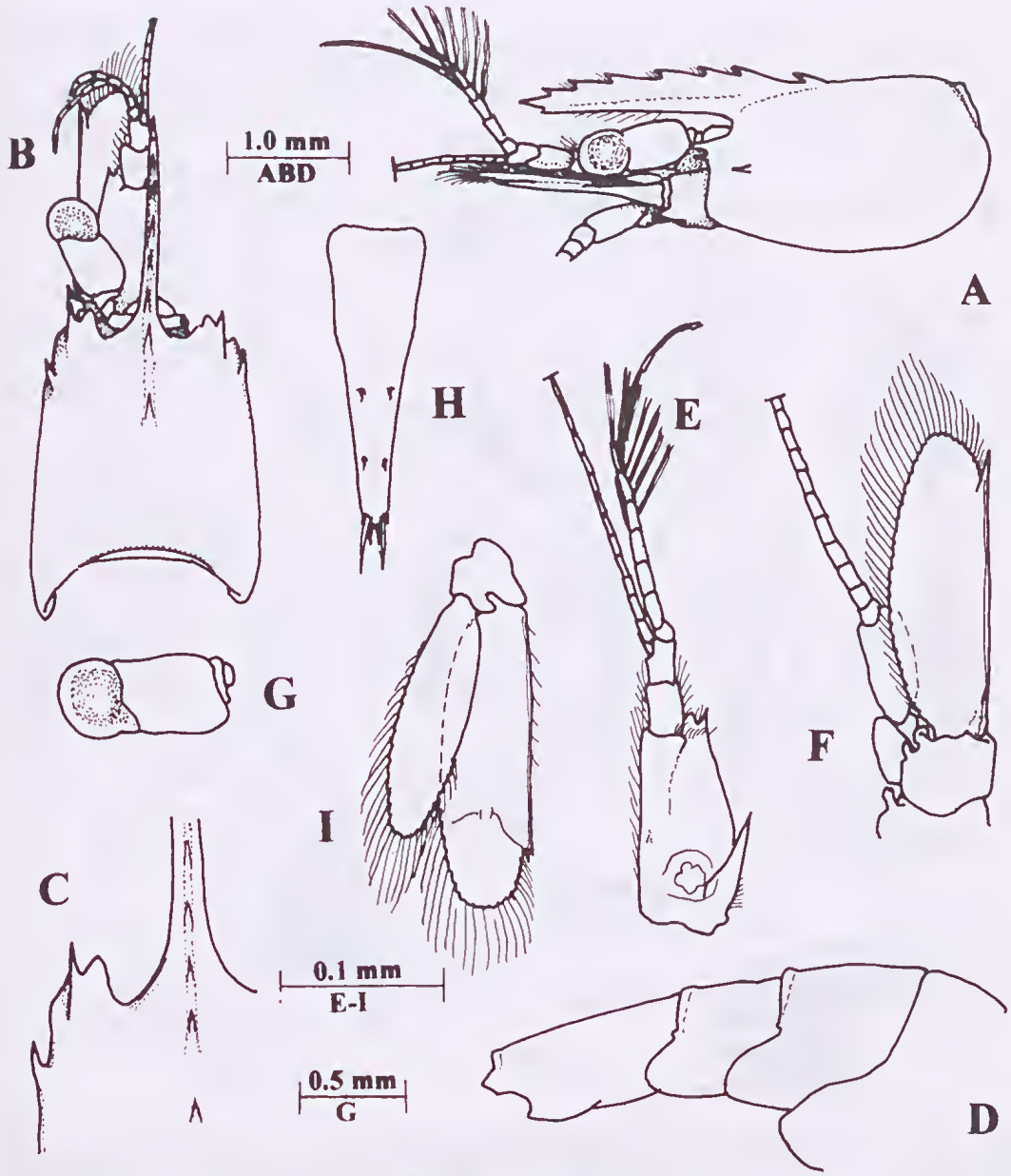

FIG. 2. *Periclimenes kallisto* sp. nov., ovig. female paratype, QMW28069, Swain Reefs. A, earapaee and appendages, lateral view; B, earapaee and appendages, dorsal view; C, left orbital region, dorsal view; D, third to sixth abdominal segments, lateral view; E, antennular pedunele; F, antennal pedunele; G, eye; H, telson; I, uropod.

developed, with granular statolith; upper flagellum biramous, proximal three segments fused, shorter free ramus with three segments, about six groups of aesthetases, longer ramus slender, short, filiform, lower flagellum longer, slender, filiform.

Antenna. Normal form (Fig. 2F), basicerite robust with strong acute distolateral tooth, distomedial angle with reflected lamina, with short subcylindrical process proximally, ischiocerite and merocerite without special features, carpocerite about 0.4 of scaphocerite length, 2.5 times longer

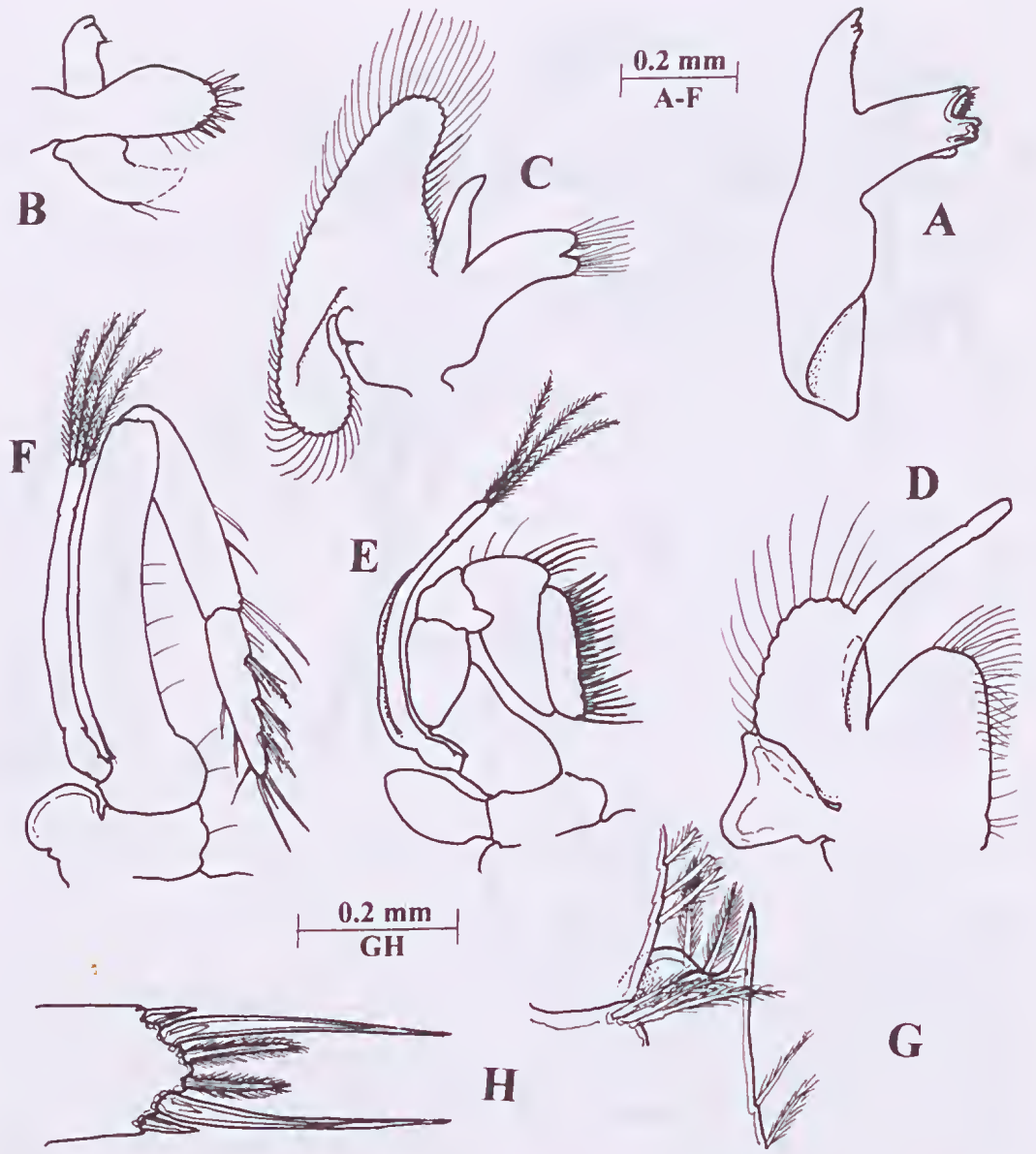

FIG. 3. *Periclimenes kallisto* sp. nov., ovig. female paratype, QMW28069, Swain Reefs. A, mandible; B, maxillula; C, maxilla; D, first maxilliped; E, second maxilliped; F, third maxilliped; G, antennule, proximal segment, distolateral angle; H, telson, posterior spines.

than central width, reaching to about 0.45 of scaphocerite length, flagellum well developed, scaphocerite well exceeding antennular peduncle, 3.0 times longer than central width, tapering slightly distally, anterior margin bluntly angular (Fig. 6B), lateral margin straight, with well developed distolateral tooth (Fig. 6C), about 0.14 of scaphocerite length, at 0.85 of length; coxa with subcylindrical process distomedially, terminally swollen, containing small spherical mass of (?) glandular cells.

Ophthalmic somite. Without median process, or median pigment spot.

Eye. Cornea globular (Fig. 2G), oblique, appearing whitish, unpigmented, without accessory spot,

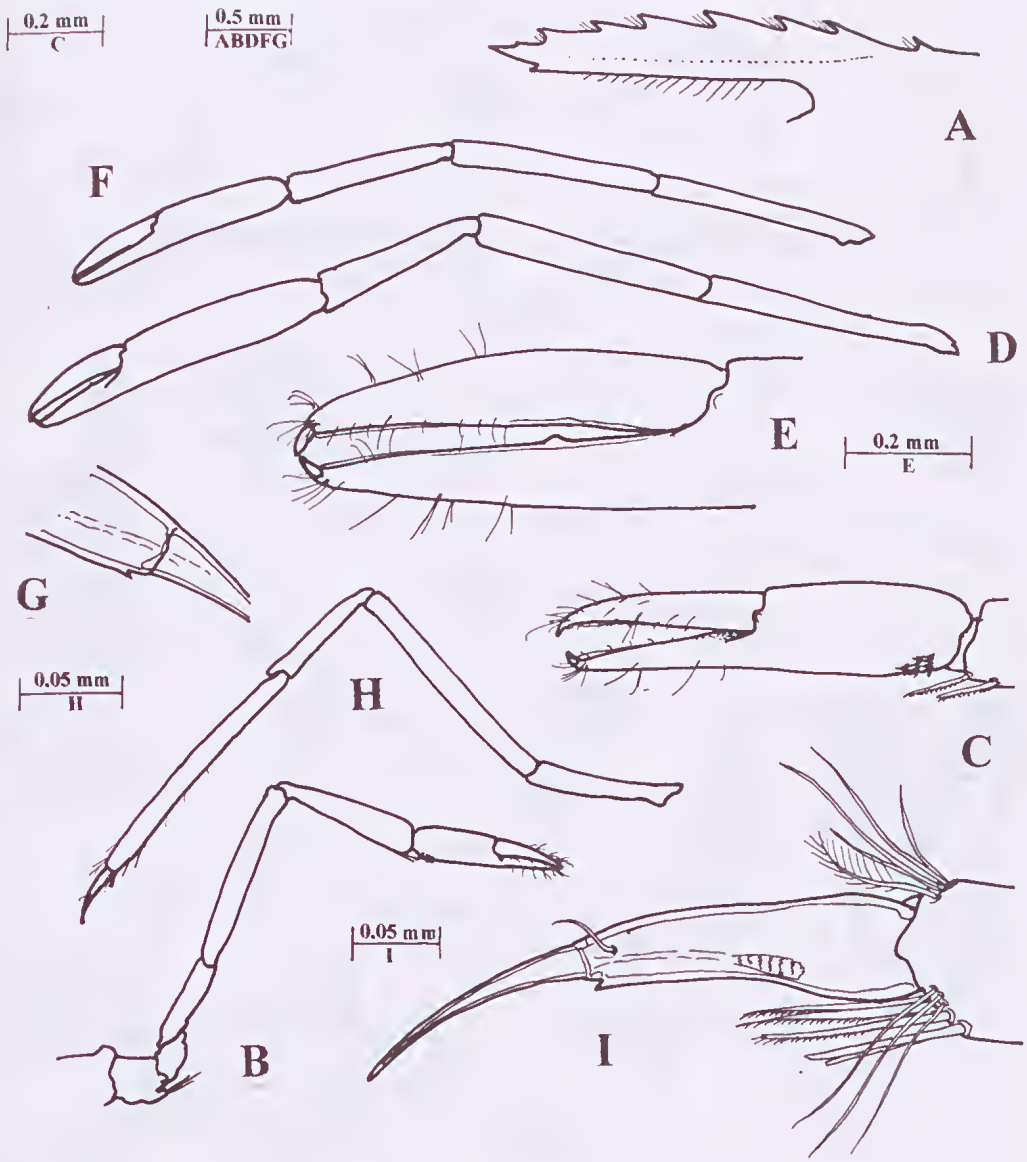

FIG. 4. *Periclimenes kallisto* sp. nov., ovig. female paratype, QMW28069, Swain Reefs. A, rostrum; B, first pereiopod; C, chela of same; D, major second pereiopod; E, fingers of same; F, minor second pereiopod; G, fourth pereiopod, unguial-corporal articulation of dactylus; H, third pereiopod; I, dactylus of fifth pereiopod.

stalk subcylindrical, 1.5 times longer than proximal width, tapering slightly distally.

Epistome. Unarmed.

Mandible. (Fig. 3A) Corpus robust, without palp, incisor process (Fig. 6E) slender, tapering distally, obliquely truncate, with three acute teeth, lateral tooth larger, central tooth smallest, medial margin with three minute denticles distally, molar process (Fig. 6D) stout, subcylindrical, distally truncate, with tridentate ventral lobe, blunt anterior and posterior lobes, spinulate dorsal lobe.

Maxillula. (Fig. 3B) Normal form, palp (Fig. 6F) feebly bilobed, with ventral tubercle bearing small simple seta, upper lacinia distally rounded (Fig. 6G) with seven stout simple spines, several

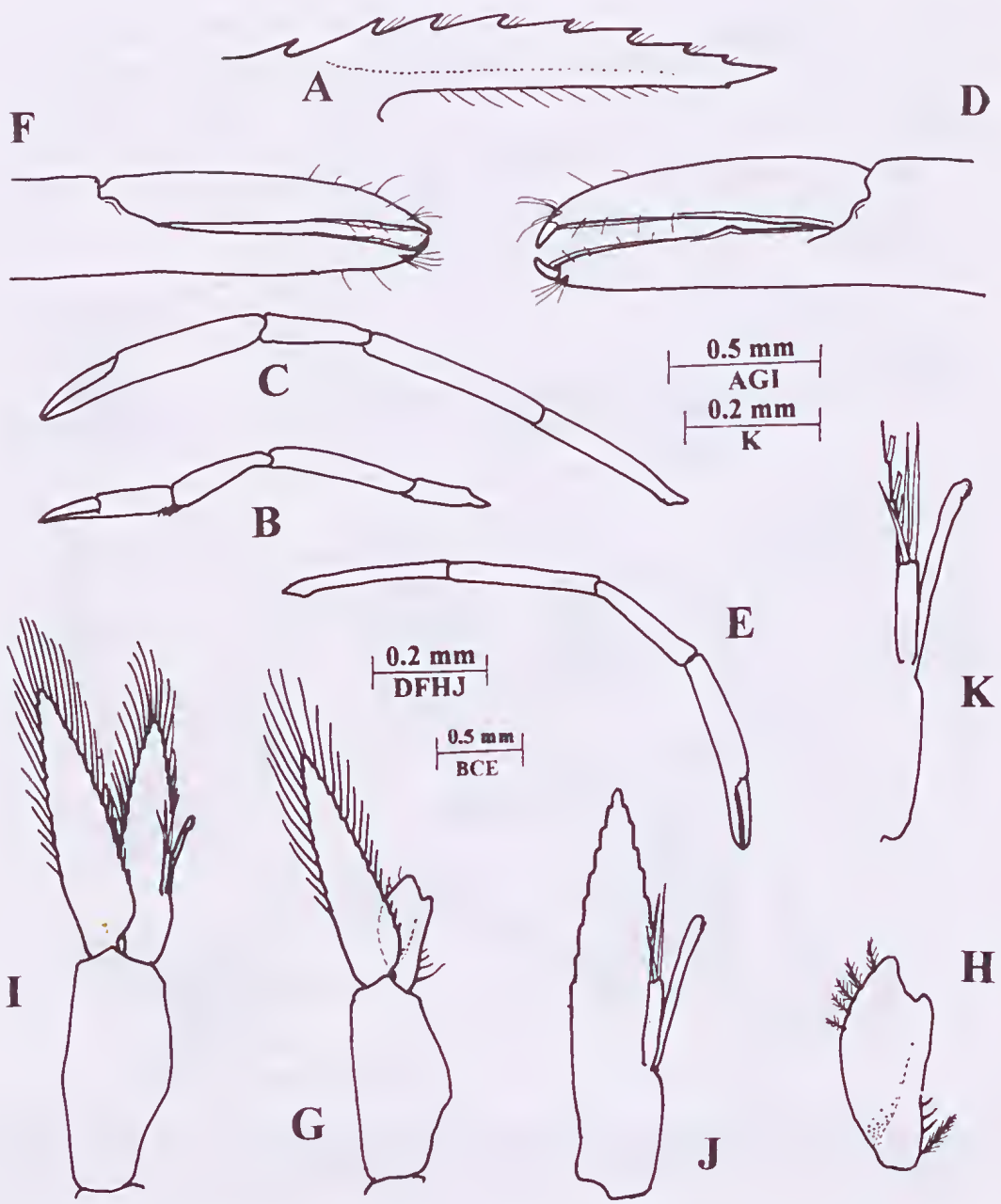

FIG. 5. *Periclimenes kallisto* sp. nov., male allotype, QMW28067, Swain Reefs. A, rostrum; B, first periopod; C, major second pereiopod; D, fingers of same; E, minor second pereiopod; F, fingers of same; G, first pleopod; H, endopod of first pleopod; I, second pleopod; J, endopod of second pleopod; K, appendiees masculina and interna of second pleopod.

simple spiniform setae, lower lacinia damaged in dissection.

Maxilla. (Fig. 3C) With flattened tapering, non-setiferous palp, about 3.0 times longer than basal width, basal endite bilobed, lobes short, subequal, with 9 and 11 slender simple terminal setae, coxal endite obsolescent, margin convex, scaphognathite well developed, about 2.75 times

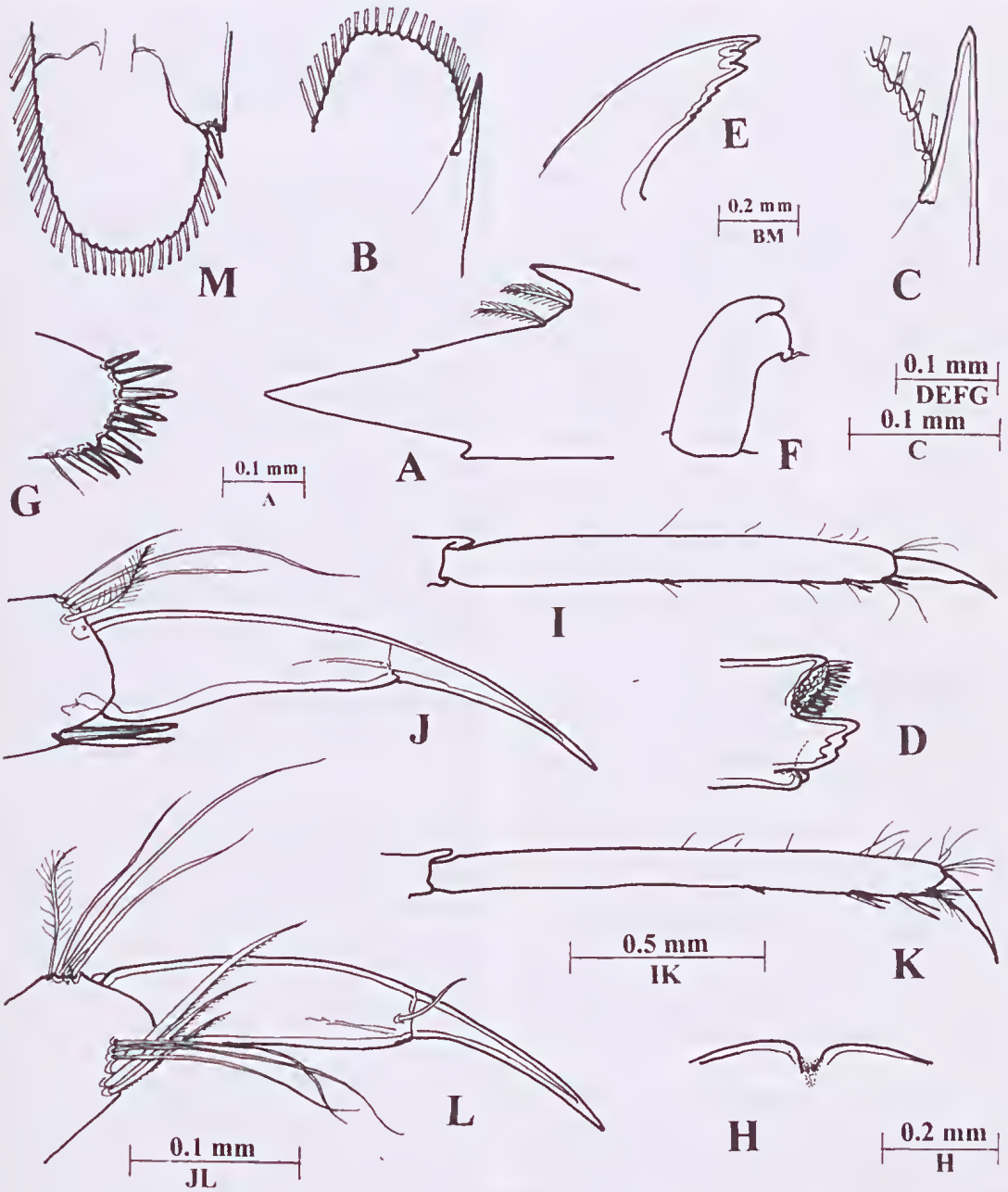

FIG. 6. *Periclimenes kallisto* sp. nov., paratypes, QMW28069, Swain Reefs. A, tip of rostrum; B, distal scaphocerite; C, distolateral tooth scaphocerite; D, mandible, molar process; E, same, incisor process; F, maxillula, palp; G, same, distal upper lacinia; H, fourth thoracic sternite; I, third pereiopod, propod and dactyl; J, same, distal propod and dactyl; K, fifth pereiopod, propod and dactyl; L, same, distal propodus and dactylus; M, uropod, distal end of exopod.

longer than wide, posterior lobe about 2.3 times longer than basal width, anterior lobe about 1.3 times, distally narrow, medial margin concave.

First maxilliped. (Fig. 3D) With simple non-setiferous palp, about 3.5 times longer than wide, basal endite well developed, broadly

rounded, medial margin straight, with sparse, slender simple marginal setae, coxal endite obsolescent, feebly concave, sparsely setose, exopod with well developed flagellum, distal setae lost in dissection, caridean lobe large, epipod small, triangular, feebly bilobed.

Second maxilliped. (Fig. 3E) Normal form, dactylar segment about 4.0 times longer than wide, medial margin straight, densely provided with serrulate spines, propodal segment with anterior margin broadly rounded, feebly medially produced, with sparse spiniform setae, carpus, ischiomerus and basis without special features, exopod with well developed flagellum, lateral margin proximally lamellar, with three plumose terminal setae, coxa with medial margin convex, non-setose, with suboval epipod laterally, without podobranch.

Third maxilliped. (Fig. 3F) With endopod reaching to about 0.5 of carpocerite length; ischiomerus completely fused with basis, combined segment bowed, about 6.0 times longer than central width, margins sub-parallel, slightly tapering distally, sparsely setose medially, basal region medially convex, penultimate segment about 0.55 of antepenultimate segment length, 4.5 times longer than central width, sparsely setose, with two long spiniform setae distolaterally, about 0.3 of antepenultimate segment length, 4.5 times longer than proximal width, tapering distally, with three small groups of serrulate spines, several longer simple spines terminally, exopod well developed, flagellum not exceeding antepenultimate segment of endopod, with four terminal plumose setae, coxa with small rounded medial margin, with semicircular lateral plate, without arthrobranch.

Thoracic sternites. Fourth without median process, with low transverse ridges (Fig. 6H) separated by small U-shaped median notch, fifth to eighth unarmed.

First pereiopod. Slender (Fig. 4B), exceeding carpocerite by 0.5 of carpus and chela; chela (Fig. 4C) with palm oval in section, tapering slightly distally, about 2.3 times longer than depth, with three transverse rows of short serrulate spinules proximally, fingers slender, subequal to palm length, about 5.0 times longer than proximal depth, sparsely setose, with stout hooked terminal spines, cutting edges laminar over distal half, entire; carpus subequal to palm length in female, 4.3 times longer than distal width, tapering proximally, with few slender serrulate spines distoventrally, shorter than chela in male (Fig. 5B); merus about 1.25 times chela length, subcylindrical, 7.0 times longer than width; ischium about 0.5 of merus length, basis short, without special features; coxa with setose distoventral process. Male first pereiopod generally similar to female, carpus shorter than chela, about 0.75 of chela length.

Major second pereiopod, female. Well developed (Fig. 4D), chela slender, about 1.1 of CL, palm subcylindrical, smooth, 4.0 times longer than depth, fingers (Fig. 4E) slender, slightly more than half palm length, dactylus slender about 5.6 times longer than proximal depth, tapering distally to stout terminal unguis, cutting edge with shallow entire lamina over distal third, proximal half thickened, unarmed, fixed finger similar, with single small acute tooth at 0.4 of length; carpus about 0.8 of palm length, 4.5 times longer than distal width, tapering proximally, unarmed; merus 1.1 times palm length 7.0 times longer than width, uniform, unarmed; ischium slender, about 1.25 times palm length, 9.5 times longer than distal width, tapering slightly proximally, unarmed; basis and coxa without special features. *Male.* (Fig. 5C) chela slender, about 0.78 of CL, palm subcylindrical, smooth, 4.8 times longer than depth, fingers (Fig. 5D) slender, about 0.65 of palm length, dactylus slender about 5.0 times longer than proximal depth, tapering distally to stout terminal unguis, cutting edge with shallow entire lamina over distal third, proximal half thickened, unarmed, fixed finger similar, with single small acute tooth at 0.4 of length; carpus about 0.65 of palm length, 3.3 times longer than distal width, tapering proximally, unarmed; merus 1.3 times palm length, 7.0 times longer than width, uniform, unarmed; ischium slender, subequal to palm length, 8.5 times longer than distal width, tapering slightly proximally.

Minor second pereiopod. Smaller (Fig. 4F), less well developed than major pereiopod; chela about 0.6 of CL, 0.85 of major chela length, palm 4.0 times longer than depth, fingers 0.8 of palm length, slender, unarmed, carpus subequal to length of major carpus, about 0.75 of palm length, 6.0 times longer than distal width, tapering proximally, unarmed; merus 1.5 times palm length, 8.5 times longer than distal width, tapering slightly proximally, unarmed; ischium slender, 1.3 times palm length, 1.1 times merus length, basis and coxa without special features. *Male.* (Fig. 5E) smaller, less well developed than major pereiopod; chela about 0.68 of CL, 0.83 of major chela length, palm 4.6 times longer than depth, fingers (Fig. 5F) 0.5 of palm length, slender, unarmed, carpus longer than major carpus, subequal to palm length, 4.7 times longer

than distal width, tapering proximally, unarmed; merus 1.1 times palm length, 8.0 times longer than distal width, tapering slightly proximally, unarmed; ischium slender, 1.2 times palm length, 1.1 times merus length.

Third pereiopod. Slender, exceeding carpocerite by carpus, propod and dactyl; dactyl (Fig. 6J) slender, about 0.25 of propod length, corpus and unguis clearly demarkated, unguis simple, slender, curved, about 6.0 times longer than basal width, 0.77 of corpus length, corpus compressed, about 2.75 times longer than proximal depth, dorsal margin feebly convex, ventral margin feebly biconvex, unarmed, with single distolateral sensory seta; propod (Fig. 6I) 10.0 times longer than wide, uniform, sparsely setose, with pair of short simple distoventral spines, about half unguis length, 0.75 of distal propod width, with pair and single similar distal ventral spines, smaller simple spine at half propod length; carpus about 0.5 of propod length, 5.5 times longer than wide, unarmed, merus subequal to propod length, 11.0 times longer than wide, unarmed, ischium subequal to carpal length, half meral length, unarmed, basis and coxa without special features.

Fourth pereiopod. Similar to third, propod about 1.1 times length of third propod, 11.5 times longer than deep, spinulation and dactylus as in third pereiopod.

Fifth pereiopod. Similar to third, propod (Fig. 6K) about 1.15 times length of third propod, 14.0 times longer than deep, with three long slender serrulate distolateral spines, two pairs of slender distal ventral spines, about twice length of third and fourth pereiopod spines, small ventral spine at 0.65 of ventral length; dactyl (Fig. 6L) 0.2 of propod length, corpus less tapering than in third pereiopod.

Male pleopods. First pleopod (Fig. 5G) normal, basipodite about 2.2 times longer than width, margins non-setose, lateral straight, medial strongly convex, exopod 1.2 times longer than basipodite, 4.5 times longer than wide, endopod (Fig. 5H) 0.5 of exopod length, about 2.8 times longer than width, distally pointed, with five short plumose setae distolaterally, medial margin with blunt accessory lobe distally, proximal margin with three short curved simple spinules, with single short plumose seta proximally. Second pleopod (Fig. 5I) similar to first, with basipodite about 1.2 times first basipodite length, 2.25 times longer than central width, exopod 1.2 times basipodite length, 4.0 times longer than width, endopod (Fig. 5J) 0.9 of exopod length, 4.7 times longer than width, appendices (Fig. 5K) at about 0.3 of medial length, corpus of appendix masculina subcylindrical, 5.0 times longer than wide, 0.22 of endopod length, with three simple terminal spines, two subequal, about 1.2 times corpus length, one shorter, 0.75 of corpus length.

Uropod. (Fig. 2I) with protopodite posterolaterally rounded; exopod reaching to end of telson, 3.0 times longer than broad, lateral margin straight, sparsely setose, with small acute distolateral tooth, with larger mobile spine medially, diaeresis well developed (Fig. 6M); endopod about 0.8 of exopod length, 3.5 times longer than broad.

Ova. Numerous, small.

MEASUREMENTS. Holotype. postorbital carapace 2.0mm, carapace and rostrum 4.75mm, total body length (approx.) 13.7mm, major second pereiopod chela 2.2mm, minor second pereiopod chela 1.3mm; ova length 0.5mm. Allotype. postorbital carapace 1.7mm, carapace and rostrum 2.7mm, total body length (approx.) 8.5mm, major second pereiopod chela 1.2mm, minor second pereiopod chela 0.95mm.

COLOUR PATTERN. Unknown.

HOST. Unidentified bushy black corals [Antipatharia].

DISTRIBUTION. Type locality. Swain Reefs. Known only from Swain Reefs and Keeper Reef, Queensland, Australia. Bathymetric Range. 10–30m.

ETYMOLOGY. The species is named after the R.V. Kallisto, of the Russian Academy of Sciences Far East Seience Center, Vladivostok.

SYSTEMATIC POSITION. *Periclimenes kallisto* is most closely related to a small group of species that includes *P. affinis* (Zehntner, 1894), *P. brocketti* Borradaile, 1915, *P. canalinsulae* Bruce & Coombes, 1997, and *P. jugalis* Holthuis, 1952. Of these, *P. kallisto* appears most closely related to *P. jugalis*, from which it is most readily distinguished by the slender ambulatory dactyls and the lack of teeth on the second pereiopod dactyls. *Periclimenes jugalis* is known from the holotype specimen from the Aru Islands, Indonesia, and four specimens from Zanzibar (Bruce, 1976).

Periclimenes brocketti Borradaile, 1915, is known from the holotype specimen only (Borradaile, 1915), which was re-described by Bruce (1978), who noted its poor condition. The close resemblance to *P. affinis*, re-described by Holthuis (1958), and possible synonymy of these species has been pointed out (Bruce, 1978, 1982; Chace & Bruce, 1993). No fresh information on

P. brocketti has since become available and, as no distinguishing characters have been discerned, *P. brocketti* Borradaile, 1915, is now formally designated as a junior synonym of *Periclimenes affinis* (Zehntner, 1894). Both species were originally reported in association with crinoid hosts.

These species may be distinguished by the following key.

1. Rostral dentition 5/0, ambulatory propods with short blunt spines ..... *P. canalinsulae* Bruce & Coombes

   Rostral dentition greater than 5/0, ambulatory propods with long acute spines 2

2. First pereiopod with carpus 1.4 times or more than length of chela; ambulatory propods with transverse rows of long setae disto-laterally; rostral dentition 6–7/1–2 ..... *P. affinis* (Zehntner)

   First pereiopod with carpus 1.2 times or less than length of chela; ambulatory propods without transverse rows of long setae distolaterally 3

3. Teeth on fingers of second pereiopod well developed, acute; ambulatory dactyls robust, rostral dentition 7/2 ..... *P. jugalis* Holthuis

   Teeth on fingers of second pereiopod obsolete; ambulatory dactyls slender, rostral dentition generally 7–9/1 (rarely /0,2) ..... *P. kallisto* sp. nov

REMARKS. Although associated with a wide variety of coelenterate hosts, few of the Indo-West Pacific species of *Periclimenes* appear to have been previously recorded in association with antipatharian hosts. Species associated with antipatharians that were earlier included in the genus *Periclimenes*, have since been transferred to other genera, such as *Kemponia nilandensis* (Borradaile, 1915) and *Manipontonia psamathe* (De Man, 1902). Two species of the restricted genus *Periclimenes* have been reported from *Antipathes* by Duris (1990), *P. brucei* and *P. zevinae*, both from about 50m in the Maldive Islands. *Periclimenes brucei* shows a close resemblance in its bodily parts to *P. kallisto* but is markedly different in the presence of one extremely elongated slender second pereiopod and distinctly biunguiculate ambulatory dactyls. *Periclimenes zevinae* also has stoutly biunguiculate ambulatory dactyls. It also has characteristic finger tips on the first pereiopod chela, which are broadly rounded and minutely multidentate, quite unlike the slender simple fingers of *P. kallisto*, or any other *Periclimenes* species.

One female specimen of *P. kallisto* was examined in which the dactyl of the third ambulatory (Fig. 4H) was as in the holotype female but the fourth had a minute distal accessory denticle (Fig. 4G). The fifth pereiopod dactyl (Fig. 4I) has a small acute distal accessory tooth.

ACKNOWLEDGEMENTS

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THE FIRST REPORT OF ZUPHIINI (COLEOPTERA: CARABIDAE) FROM NEW CALEDONIA; A NEW GENUS AND TWO NEW SPECIES.

JONG KYUN PARK AND KIPLING W. WILL

PARK, J.K. & Will, K.W. 2008 04 30. The first report of Zuphiini (Coleoptera: Carabidae) from New Caledonia; a new genus and two new species. *Memoirs of the Queensland Museum* **52**(2): 99–104. Brisbane. ISSN 0079-8835.

A new zuphiine carabid beetle genus, *Atongolium* gen. nov., including *Atongolium mirabile* sp. nov. (type species) and *A. moorei* sp. nov., is described. The type locality for both new species is Ningua Reserve, New Caledonia. These are the first Zuphiini recorded from New Caledonia. They are very divergent from all known zuphiines in having the anterior and posterior corners of the pronotum with lobe-like protuberances, a field of spatulate setae covering most of the body and a coating of environmental patina. Their coating of dirt renders them very cryptic. ❐ *Systematics, species key, crypsis, New Caledonia, Coleoptera, Carabidae, Zuphiini.*

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Worldwide there are 320 species belonging to 21 genera of the tribe Zuphiini Bonelli (Lorenz, 2005a, b). Many zuphiine genera have been described and revised that are found in the region adjacent to New Caledonia (Baehr, 1984, 1985, 1986, 2004) and distributed in the Oriental region (e.g. Baehr, 1997, 1998). However, this tribe has not been previously reported from New Caledonia. Works on New Caledonian Carabidae are limited, e.g. (Perroud & Montrouzier, 1864; Fauvel, 1882a, b, e, 1903; Jeannel, 1944; Heller, 1916; Everard, 1936), and there has never been a comprehensive faunal work for the group on the island. As a result of recent collecting efforts by the Queensland Museum at numerous sites in New Caledonia there are many new records and taxa being discovered. In this contribution we report the first collection of Zuphiini for New Caledonia and describe these extremely morphologically divergence taxa.

METHODS

Dissection methods for male genitalia, measurements and descriptive terms follow Will (2002). Images were taken using a Mieropties XLT digital imaging system. Abbreviations used are as follows: L - length of body (from labrum to apex of elytra), LH - length of head, WH - width of head, LP - length of pronotum, WP - width of pronotum, LE - length of elytra, WE - widest width of elytra, LAI - length of anterior lobe of prontum, LPI - length of posterior lobe, LA1 - length of antennomere 1, WA1 - width of antennomere 1.

Museum codens used herein: QM, Queensland Museum, Brisbane; MNHN, Muséum National d'Histoire Naturelle, Paris.

TAXONOMY

Atongolium gen. nov.

TYPE SPECIES. *Atongolium mirabile* sp. nov.

ETYMOLOGY. The generic name is a latinised arbitrary combination of letters created by B.P. Moore during his initial study of specimens in the QM. Neutral gender.

DIAGNOSIS. This is the only genus of Zuphiini known from New Caledonia and can readily be distinguished from all other genera in the tribe by a combination of the following, projecting lobes at the anterior and posterior angles of pronotom (Figs 1, 2), dorsal surface of body with spatulate setae, enlarged antennomere 1, elytral interval 5 carinate and 7 tuberculate and apex of elytron acuminate to dentiform.

DESCRIPTION. Colour of integument of cleaned specimens (environmental patina removed) dark red-brown; antennae, legs and palpi concolourous with body to slightly lighter. General body-form (Figs 1, 2) slightly dorso-ventrally depressed, slender and long. Body with spatulate setae of different lengths sparsely distributed over most of dorsal surface, more densely on legs

and near margins of elytra and pronotum. Dorsal surface naturally coated with an environmental patina, apparently of soil and exudates. *Head.* Form elongate, parallel-sided. Eyes small, more or less round, little protruding. Clypeus trapezoidal, anterior and lateral margins distinctly elevated with long seta on either side. Region between antennae near antennal base with large, deep groove. Frons smooth, slightly convex. Labrum almost rectangular with 6 marginal setae, the inner 4 half as long as outer 2. Mandible long and slender, slightly curved at apex. Mentum wide with distinct paramedial pits, tooth simple. Maxillary palpus long, fusiform; terminal and basal seg-ment equal in length. Labial palpus elongate. Total length of antennae almost attaining elytra humeri, antennomeres pubescent, antennomere 1 asymmetrically swollen, distinctly longer and wider than other antennomeres. *Pronotum.* Slightly wider than head. Anterior and posterior angles with long, stout lobular protuberances, anterior lobes shorter and thicker than posterior pair. *Elytra.* Ovoid elongate and slightly convex, humeri sharply and obliquely sloped with inclination of about 45°, widest at midpoint. Eight elytral intervals, striae marked by row of punctures. Apex of elytra ranging from sinuate to featuring prominent, broad dentieles.

TABLE 1. Measurements of types of *Atongolium mirabile* sp. nov. (mm).

Types	WH	LH	WP	LP	WE	LE	LAI	LPI
Holotype	0.90	1.44	1.20	1.30	2.00	3.45	0.12	0.22
Paratype (Ningua)	0.90	1.52	1.18	1.36	2.00	3.45	0.12	0.24
Paratype (Col d'Amieu)	1.00	1.62	1.22	1.40	2.20	3.50	0.10	0.20

TABLE 2. Measurements of types of *Atongolium moorei* sp. nov. (mm).

Types	WH	LH	WP	LP	WE	LE	LAI	LPI
Holotype	0.76	1.22	0.88	0.88	1.74	2.70	0.10	0.20
Paratype (Ningua)	0.78	1.26	0.86	0.84	1.77	2.67	0.10	0.20
Paratype (Col d'Amieu)	0.74	1.18	0.78	0.92	1.55	2.57	0.10	0.20

KEY TO ADULTS OF *ATONGOLIUM*

1. Lateral pronotum between pronotal lobes clearly margined and with a continuous carina from apex to base. Antennomere 1 fairly long and wide (HL/LA1: 2.88, WH/WA1: 6.43). Length of body >6.0mm ..... *Atongolium mirabile* sp. nov. (Fig. 1A)
2. Lateral pronotum between pronotal lobes not margined, smoothly rounded and without carina. Antennomere 1 very long and wide (HL/LA1 :1.93, WH/WA1: 3.30). Length of body <6.0mm ..... *Atongolium moorei* sp. nov. (Fig. 1B).

Atongolium mirabile sp. nov.
(Figs 1A, 2, 3A-F, 4)

ETYMOLOGY. From the Latin *mirabile*, meaning wonderful or extraordinary.

MATERIAL. HOLOTYPE, ♂: NEW CALEDONIA, 21°45'S × 166° 09'E, Ningua Reserve Camp, 1100m, 12-13.xi.2001, C. Burwell & G. Monteith, pyrethrum, trees & logs, 8639 (MNHN). PARATYPES(2 ♂♂3 ♀♀): 1♀, same data as holotype (QM); 1♂, same locality, 29.i.2002, G. Monteith, pyrethrum, tree trunks, 8897 (QM); 1♀, 21° 37'S × 165°49'E, Col d'Amieu, west slope, 470m, 29.ix.2004, G. Monteith, pyrethrum, trees & logs, 11667 (QM); 1♀, Riviere des Pirogues (headwaters, 350–400m), 22.v.1984, G. Monteith & D. Cook. (QM); 1♂, Mt. Koghis, montane forest, 500m, 22-24.v.1987, N.I. Platnick & R.J. Raven. (MNHN).

DESCRIPTION. Total length of holotype 6.30 mm, greatest width 2.00 mm. General body-form as in Figs 1A, 2. Measurements as in Table 1. *Antennae.* Antennomere 1 longer and distinctly wider than all other antennomeres, 3.50 × as wide and 5.60 × as long as antennomere 2. *Pronotum.* Longer than wide (LP/PW: 1.08), ovoid and convergent to base, greatest width slightly broader than head. Lobes at anterior angles shorter (0.12mm) and relatively thicker than lobes at posterior angles (length 0.22mm). Lateral margin between lobes with prominent continuous carina. *Elytra.* Intervals 1, 3 and 5 with row of regularly spaced setae, setae longer than those of intervals 2, 4, 6 and 7. Intervals 2, 4, 6 and 7 with scattered setae. Interval 3 near apex with 2 tubercles, apical-01/3. Intervals 4 and 5 anastomosing near base. Interval 5 carinate for most of its length. Intervals 7-8 with 12 tubercles surmounted with umbilicate punctures. Striae well impressed and punctate. *Legs.* Protarsi of male slender, not expanded, without ventrally adhesive hairs, tarsomere 1 ventrally with 7 stout setae medially and laterally, tarsomeres 2 to 4 with short to long setae, setae longer near apex, tarsomere 5 with 3 moderately long setae. Inner seta of tarsomere 4 ventro-apically positioned, long and translucent. *Male genitalia.* Genital ring wide and long. Median lobe (Fig.

FIG. 1. *Atongolium* species, dorsal view of cleaned specimens. A, *Atongolium mirabile* sp.nov.; B, *Atongolium moorei* sp.nov.

3A-D) of aedeagus slightly twisted to left in apical third, ostium deflected slightly to left, no structures apparent on endophallus in cleared specimen. Tip from level of ostium to apex bent to right of midline, tip beyond ostium short, broad, rounded at apex. Left paramere wide and elongate, right paramere slightly twisted and more slender. *Female genitalia*. Gonocoxite-1 with row of six stout setae along apicoventral margin, gonocoxite-2 with two nematiform setae in apical furrow, two ventolateral and one dorsomedial ensiform setae.

Atongolium moorei sp. nov.
(Figs 1B, 3G-K, 4)

ETYMOLOGY. Noun in the genitive case. In honour of Barry P. Moore, who first recognised this remarkable group among the material in the Queensland Museum and for his contributions to Australian entomology.

MATERIAL. HOLOTYPE, ♂: NEW CALEDONIA, 21°45' S × 166° 09' E, Ningua Reserve Camp, 1100m, 12-13.xi.2001. C. Burwell & G. Monteith, pyrethrum, trees & logs. 8639 (MNHN). PARATYPES (2♀♀): 1♀, NEW CALEDONIA, 21° 45' S × 166° 09' E, Ningua, nr summit, rainforest, 1300m, 13.xi.2001, G. Monteith, Berlesate No.1052, sieved litter (QM); 1♀, 21° 37' S × 165° 49'E, Col d'Amieu, west slope, 470m, 25.xi.2003, G.Monteith, pyrethrum, trees & logs, 11427 (QM).

DESCRIPTION. Total length of holotype 5.20mm, greatest width 1.74mm. General body-form as in Fig. 1B. Measurements as in Table 2. *Antennae*. Antennomere 1 longer and distinctly wider than all other antenomeres, 4.60 × as wide and 4.85 × as long as antennomere 2. *Pronotum*. Oval, sides arcuate and slightly narrower at base, greatest length and width equal (PL/PW: 1), wider than head. Anterior angles with lobes shorter (0.10mm) and relatively slightly thicker than lobes at posterior angles (length 0.20mm). Lateral margin between lobes low, smoothly rounded. *Elytra*. Intervals convex, interval 5 carinate near base, intervals 7-8

FIG. 2. *Atongolium mirabile*, uncleaned specimen with environmental patina intact. A, left lateral view; B, dorsal view; C, detail of humeral region of elytron showing environmental patina.

with 11 tubercles surmounted with umbilicate punctures. Interval 3 with 1 such tubercle near apex. Intervals 1, 3 and 5 with row of regularly spaced setae, setae longer than those of intervals 2, 4, 6 and 7. Intervals 2, 4, 6 and 7 with scattered setae. Striae marked by rows of punctures. *Male genitalia* (Fig. 3G-K). Genital ring wide and long. Median lobe of aedeagus notably twisted to right in apical third, ostium deflected to right, no structures apparent on endophallus in cleared specimens. Tip from level of ostium to apex slightly sinuate, tip beyond ostium long, narrow obliquely rounded at apex. Left paramere wide and elongate, right paramere long and slender. *Female genitalia.* Not examined.

DISCUSSION

RELATIONSHIPS. Relatively little is certain in regards to the phylogenetic relationships of subtribal and generic groups of Zuphiini. Four subtribes are known from the Austral-Asian region, but none of the included taxa appear to be particularly similar to *Atongolium*. Peculiarities of the antennae in *Atongolium* seem to distinguish this genus from Leleupidiina, which lack the enlarged first antennomere, and Patriziina, which have much shorter antennae. Both general body form and the pluri-striate elytra in Planetina, as compared to the very distinctive form of the elytra in *Atongolium*, suggest that these are long separated taxa. Given the lack of obvious synapomorphies we place *Atongolium* as incerta sedis in Zuphiini as a highly apotypic form.

DISTRIBUTION AND BIOLOGY. These curious Carabidae are quite rare. Six specimens of *A. mirabile* and three of *A. moorei* are now known from just five localities in New Caledonia (Fig. 4), all collected by Queensland Museum surveys. These are wet rainforest sites at moderate to high altitude (350-1300m) in the southern half of the island. The two species are sympatric at two localities (Col d'Amieu and Ningua). Ningua Reserve is the type locality for both species and the exact collection site is an area at 21°44'46"S X 166°09'16"E where the highest part of the mining road traverses the lower edge of the rainforest just southeast of the summit of the mountain. The larger species, *A. mirabile*, is found at all known localities while the smaller

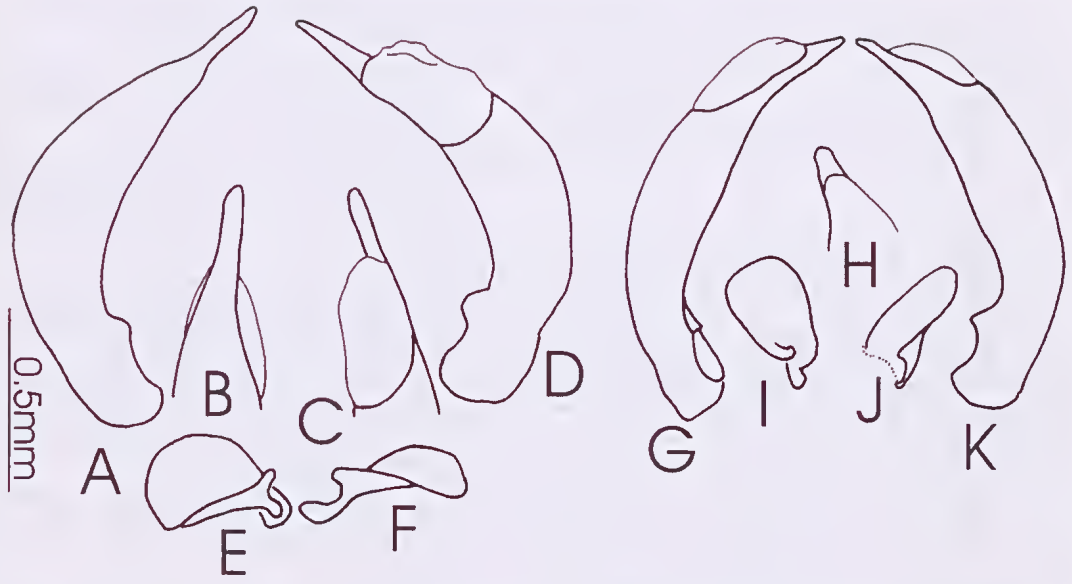

FIG. 3. *Atongolium* species, male genitalia. A-F, *A. mirabile*. A, median lobe, left lateral view; B, median lobe, ventral view of tip; C, median lobe, dorsal view of tip; E, left paramere; F, right paramere. G-K, *A. moorei*. G, median lobe, left lateral view; H, median lobe, ventral view of tip; I, left paramere; J, right paramere; K, median lobe, right lateral view.

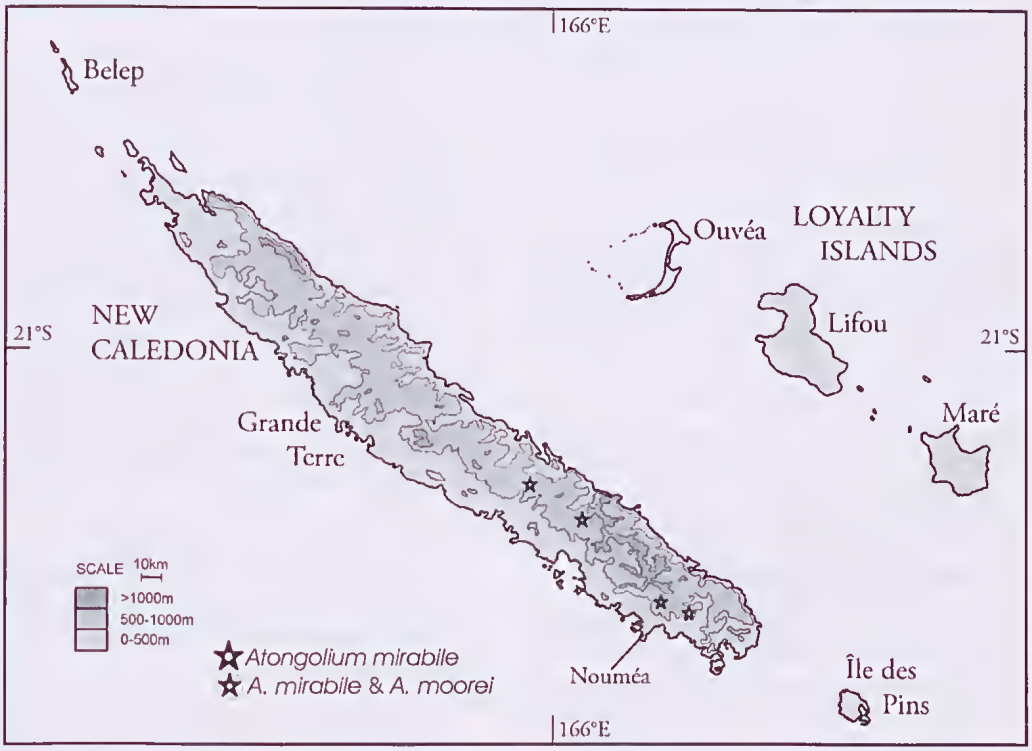

FIG. 4. New Caledonia, showing collecting sites for *Atongolium* species.

species, *A. moorei*, occurs only in the northern part of the generic range. The apparent restriction of the genus to the southern half of the island is likely real, as the Queensland Museum has intensively surveyed numerous similar sites in the northern half of the island using the same collecting methods.

No specimens have been observed in life but some speculation can be made on their microhabitat from the collection data. Two specimens have no collection method recorded. One (*A. moorei)* was from Berlese extraction of a sample of sifted ground litter. This is clearly not a common situation for the genus because the Queensland Museum has processed hundreds of New Caledonian litter samples over the years. Six specimens (two *A. moorei* and four *A. mirabile*) were from four separate pyrethrum spraying events that targeted the basal trunks of standing trees and the sides of fallen logs. At higher altitudes these surface are commonly covered with a dense layer of moss, liverworts and other epiphytes. It would seem that the normal habitat for *Atongolium* may be within the interstices of this epiphytic growth or the decayed wood/ bark surface itself. In this situation the extreme crypsis afforded by their surface coating may allow them to act as sit-and-wait predators on other small arthropods in the same habitat, while providing protection from larger, visual predators. This microhabitat differs from that of most Zuphiini, which is on the ground surface.

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PIPESTELA, A NEW GENUS OF AXINELLIDAE (PORIFERA: DEMOSPONGIAE: HALICHONDRIDA) AND DESCRIPTION OF THREE NEW SPECIES

BELINDA ALVAREZ, JOHN N.A. HOOPER AND ROB W.M. VAN SOEST

Alvarez, B., Hooper, J.N.A & Van Soest, R.W.M. 2008 04 30: *Pipestela*, a new genus of Axinellidae (Porifera: Demospongiae: Haliehondrida) and deseription of three new speeies. *Memoirs of the Queensland Museum* **52**(2): 105–118. Brisbane. ISSN 0079-8835.

The new genus *Pipestela* is ereated to inelude axinellid sponges with lamellate, branehing or tubular growth form bearing mainly oxeas arranged in a distinetive loose skeleton of vaguely plumose and wavy spieulo-fibres. The genus is known only from northeastern Australia, from the Great Barrier Reef, Coral Sea, Papua New Guinea, Solomon Islands and Vanuatu, with a single speeimen known so far from Western Australia. Type speeies *Pipestela candelabra* sp. nov. is the most widely distributed of the five known speeies, and in some plaees forms highly abundant local populations. *Pipestela rara* sp. nov., *P. occidentalis* sp. nov., *P. hooperi* (Van Soest et al.) n. eomb. and *P. terpenensis* (Fromont) n. eomb. are also assigned to this new genus. All speeies are associated with eoral reefs, in relatively elear water, between 10–50m depth. The genus shows affinity to *Cymbastela* in the predominanee of oxeas, and to *Auletta* by the eommon organ-pipe morphology, but is distinet from the former by the loose skeleton and from the latter by its lack of styles and wavy diaetinal spieules. The phylogenetie relationships of *Pipestela*, its position in the higher elassifieation, and the limits of its spatial distribution are further investigated. The definition of *Cymbastela* is revised as a eonsequenee of ereeting this new genus
❑ *Porifera, Demospongiae, Axinellidae, Pipestela n. gen., new species, coral reef sponges, Cymbastela, revision.*

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19 September 2007.

According to the revision of Alvarez & Hooper (2002) the family Axinellidae now includes ten genera: *Auletta, Axinella, Cymbastela, Dragmacidon, Dragmaxia, Pararhaphoxya, Phakellia, Phycopsis, Ptilocaulis* and *Reniochalina*. Both the family and its genera lack synapomorphies, instead diagnosed by unique combinations of plesiomorphic characters that ultimately create ambiguities for the allocation of species – particularly those with intermediate or modified characters. Other types of evidence, such as molecular DNA sequences or bio-organic chemistry (Alvarez et al., 2000; Erpenbeck et al., 2005), indicate that Axinellidae and some of its genera (e.g. *Axinella*) are polyphyletic taxa. Therefore, despite the types of characters, or the combination in which they are used within the current systematics, only few genera of this family can be distinguished currently beyond reasonable doubt. This present paper is a contribution to resolve these inconsistencies within the current systematics.

Sponges of the family Axinellidae are currently allocated to the order Halichondrida (Alvarez & Hooper, 2002), and defined by the absence of a specialised ectosomal skeleton, the characteristics of the surface, the architecture of the choanosomal skeleton and spicule geometries. Axinellidae exhibit a great diversity of shapes (e.g. encrusting, massive, branching, fan-shape, lamellate, tubular), although erect or stalked, arborescent branching forms are common. Colour is frequently within or close to the red spectrum being commonly shades of carotenoid pigments, including red, orange, yellow and brown. The choanosomal skeleton is often compressed in the axis, creating a differentiation between axial and extra-axial regions, particularly evident in species with branching and arborescent shapes. Compression of the skeleton is also observed in the peduncle of stalked species. Plumose spicule-fibres or tracts of oxeas, styles, or both, are generally a common feature among axinellid species. The presence of oxeas and styles in the same size category is also a distinctive feature of most axinellid sponges but in some species one

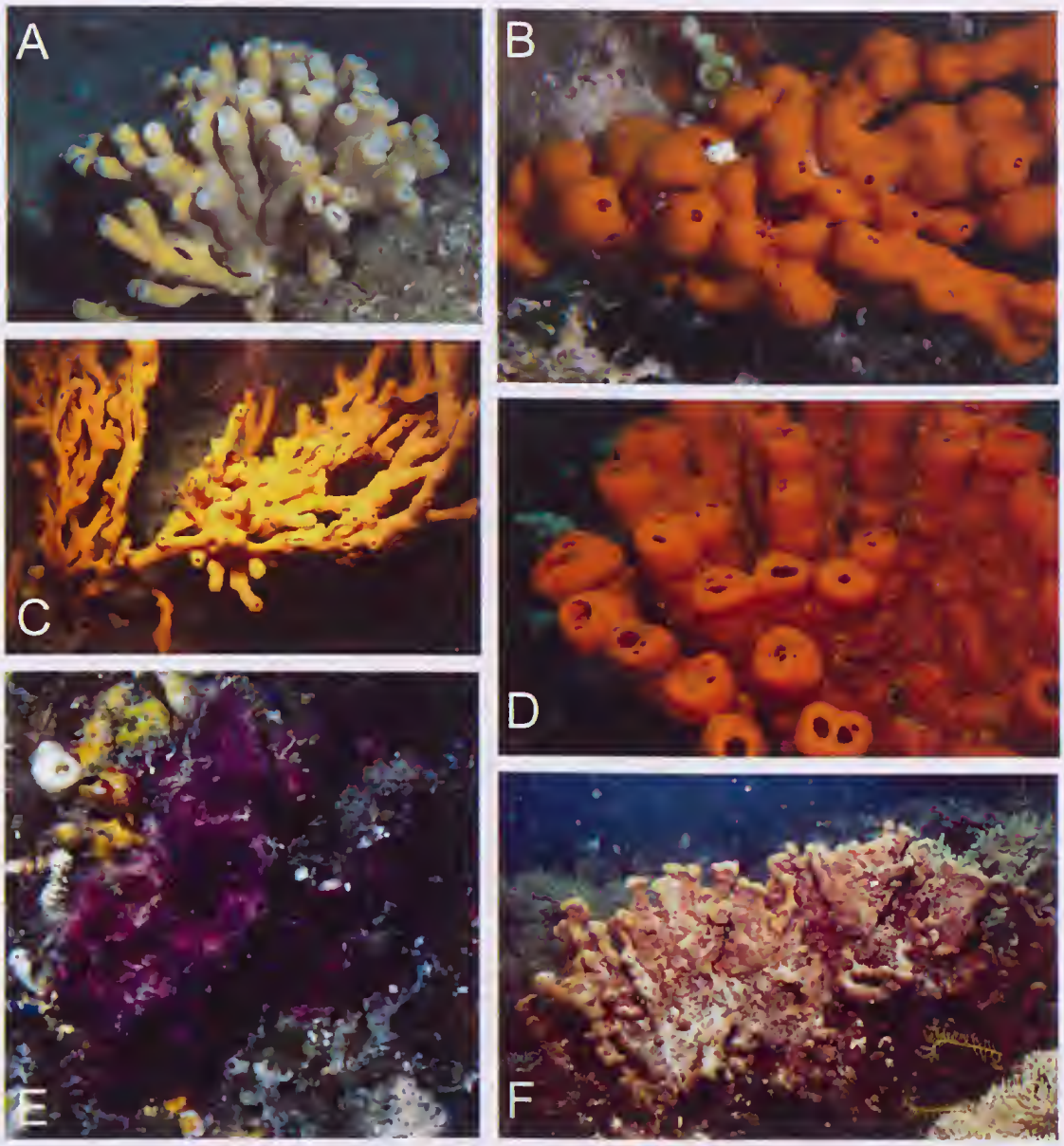

FIG. 1. A–D, Different growth forms of *Pipestela candelabra* sp. nov. *in situ*. A, 0CDN1949-C. B, 0CDN1807-X (paratype). C, QMG312951. D, 0CDN8208-H. E, *P. rara* sp. nov., QMG 319301, holotype photographed *in situ*. F, *P. terpenensis* comb. nov. *in situ*, NTMZ004057.

or the other spicule type may be absent or rare (e.g. *Cymbastela* spp. having only oxeas, or *Ptilocaulis* spp. having mainly styles).

The family Axinellidae has a cosmopolitan distribution and according to the World Porifera Database (http://www.vliz.be/porifera/index.php) currently includes 342 valid species. Previous revisions at regional levels record 15 species for New Caledonia, 11 for New Zealand, 21 for the Central-West Atlantic region, and 17 for the NE Atlantic (Alvarez & Hooper, 2002 and references within). At least 57 axinellid species are represented in Australia (Hooper & Wiedenmayer, 1994, with subsequent updates available online, 2004) but no regional revision of the fauna has so far been undertaken, and this estimate requires closer confirmation. Studies in progress, and limited

at this stage to northern Australia (Alvarez and Hooper, unpublished data), indicate that at least 60 species of Axinellidae are represented across the northern region of Australia. One of these species is a very common sponge found throughout the Great Barrier Reef, Coral Sea in Australia, Papua New Guinea and adjacent regions, and is here assigned to a new genus and species with features that agree with the definition of Axinellidae, and in particular with some apparent affinities to the genera *Auletta* and *Cymbastela*. The genus is erected to accommodate this species and several less common sponges bearing mainly oxeas as in *Cymbastela*, but lacking its characteristic cup-shape, and with distinctive loose skeletons of vaguely plumose and wavy spicule-fibres dissimilar to the highly spiculose and tightly meshed spicule tracts found in *Cymbastela*.

METHODS

Sponge collections acquired by the authors and others throughout northern Australia and the Indo-Pacific were examined in the institutions listed below. Specimens were prepared for light microscopy using the usual methods (e.g. Van Soest & Hooper, 2005). Spicule measurements are based on 25 spicules of each category and denoted as range (and mean ± 1. S.E.) of length and width. Measurements were made using a digital video camera attached to a light microscope in combination with the software V++ Precision Digital Imaging System v 4.0 (© Digital Optics, Ltd). The higher systematic arrangement follows Hooper & Van Soest (2002).

ABBREVIATIONS. CRRF, Coral Reef Research Foundation, Palau. GBR, Great Barrier Reef. MHNG, Muséum d'Histoirie Naturelle, Geneva. MSNG, Museum of Natural History of Genoa. NCI, U.S National Cancer Institute collections. NTM, Museum and Art Gallery of the Northern Territory (formerly Northern Territory Museum), Darwin. ORSTOM (now IRD), Institut de Recherché pour le Développement (IRD Noumea), New Caledonia. QM, Queensland Museum, Brisbane. ZMA, Zoologisch Museum, University of Amsterdam, WAM, Western Australian Museum.

SYSTEMATICS

Class DEMOSPONGIAE Sollas, 1885
Order HALICHONDRIDA Gray, 1867
Family AXINELLIDAE Carter, 1875

Pipestela gen. nov

DEFINITION. Axinellidae with choanosomal skeleton formed by a loose reticulation of plumose and wavy paucispicular to multispicular tracts of relatively thin oxeas.

DIAGNOSIS. Lamellate, branching or tubular growth form. Surface smooth, consistency elastic, rubbery. Ectosomal skeleton not specialised. Choanosomal skeleton slightly compressed toward the axis or centre of sponge, formed by a loose reticulation of plumose and wavy multispicular to paucispicular tracts coring ill-defined spongin fibres in some cases. Primary spicule-fibres connected by secondary thinner and shorter tracts, uni- or paucispicular. Interstitial free spicules abundant. Megascleres are thin oxeas, curved, flexuous or sinuous, often with asymmetrical ends and a wide axial channel frequently visible. Some with stylote modified ends.

TYPE SPECIES. *Pipestela candelabra* sp. nov. (here designated)

ETYMOLOGY. English for pipe and Latin *–stela-* for column; *Pipestela*, reflecting the predominant growth form of the type species. Gender: feminine.

DISTRIBUTION. Common on the Great Barrier Reef, Papua New Guinea and Solomon Islands, with outlying populations in the Coral Sea territories, northwestern Australia and Vanuatu.

REMARKS. The genus is erected to include the type species, two less common species *Pipestela rara* sp. nov. *P. occidentalis* sp. nov., and two other species previously assigned to *Cymbastela*, *P. hooperi* (Van Soest et al., 1996) and *P. terpenensis* (Fromont, 1993). These species share most skeletal features with slight variation in the size and general shape of oxeas. The wavy thin spicule tracts of oxeas encased in ill-defined spongin fibres are reminiscent of some haplosclerid genera, such as *Amphimedon* Duchassaing de Fonbressin & Michelotti, 1864 which was the original allocation of *P. terpenensis*. However, *Amphimedon* has a specialised ectosomal skeleton that is absent in *P. terpenensis*. Further, recognised species of *Amphimedon* across the Indo-Pacific, are typically blue spectrum colour (blue, grey, lilac,

green, tan). With the exception of *P. hooperi* all species develop tubular or cylindrical projections with oscula either at the apex of tubes or on the lateral sides of the tubes/branches. Within Axinellidae, this type of growth form is seen in *Auletta* Schmidt, 1870, but that genus has a clearly reticulated skeleton of robust styles and sinuous strongyles.

Pipestela candelabra sp. nov
(Figs 1A–D, 2, 3)

Clathria sp.; Mead & Beckett Publishing, 1984: 159 (top figure)

Auletta sp.; Colin & Arneson, 1997: 31, 36, 37, 121, figs 59, 89, 90, 121

Axinella sp.; Colin & Arneson, 1997: 37, fig. 92

Auletta constricta; Crews et al., 1994: 2932; Hooper et al., 1999 : 259; Sonnenschein et al., 2004: 779.

Not *Auletta constricta* Pulitzer-Finali, 1982: 95, fig. 6.

Pseudaxinyssa sp.; Silva, Andersen & Allen, 1990: 489.

Cymbastela sp.; Coleman, Van Soest & Andersen, 1999: 1137.

MATERIAL EXAMINED. HOLOTYPE: QMG320790, Houghton Reef, Howick Grp, GBR (northern sector), 14°31.1901' S,144°58.9' E, 20 m, 3.07.2003.

PARATYPES: QMG320362, JEWELL REEF, N OF CAPE FLATTERY, GBR (NORTHERN SECTOR), 14°25.99' S,145°21.42' E, 15m , 28.06.2003. QMG303078, NE Cape Grenville, Shelburne Bay CSIRO stn.26, GBR, 11°30.1001' S,143°4.04' E,

TABLE 1. Comparison of spicule dimensions among species of *Pipestela*. Measurements in micrometres.

Specimen	Locality	Length	Width
Pipestela candelabra			
	GBR, Northern sector		
QMG320790 (holotype)	Houghton Reef	158.29–234.9 µm (195.88±20.52)	2.44–5.05 µm (3.76±0.71)
QMG320362 (paratype)	Jewell Reef	131.34–213.94 µm (173.32±22.22)	1.87–5.62 µm (3.91±0.91)
QMG303078 (paratype)	NE Cape Grenville	117.47–205.06 (164.52±24.95)	1.06–3.67 (2.42±0.51)
	Papua New Guinea		
CRRF 0CDN1801-X (paratype)	Coral sea SW Port Morsby	153.57–219.35 µm (191.97±19.58)	1.99–3.37 µm (2.73±0.5)
QMG312951	Keppel Pt	191.9–547.24 µm (352.09±114.56)	3.45–10.79 µm (6.14±1.69)
0CDN8208H	Woodlark Is	145.49–217.8 (173.06±17.87)	2.27–3.98 (2.76±0.47)
	GBR, Cairns–Cooktown sector		
QMG304178	Lizard I.	124.7–208.43 (184.2±19.53)	1.71–4.59 (3.25±0.7)
QMG307657	Low Isles	194.53–276.94 (230.44±21.86)	4.36–9.79 (7.13±1.53)
	GBR, Townsville–Whitsunday sector		
QMG303845	South Triangle Reef	159.95–228.63 (193.77±15.73)	2.07–3.77 (3.03±0.42)
	Vanuatu		
QMG306899	Malekula	152.04–426.54 µm (260.24±73.48)	1.54–3.29 µm (2.43±0.38)
P rara			
QMG319301	Holmes Reef, Coral Sea	171.82–309.65 (275.48±35.59)	2.93–6(4.8±0.72)
*P. hooperi**			
MHNG 18990 (holotype)	Kelso Reef, GBR	163–269 (232)	3–10 (6.4)
*P. terpenensis***			
QMG025039 (holotype)	Lizard Is., GBR	218–319 (237)	2.5–4.2 (3.4); 6.7–12.6 (8.7)
P. occidentalis			
NTM Z003366	Barrow Is., Western Australia	150.61–217.34 (183.8±19.74)	3.29–5.72 (4.48±0.73)

* From Van Soest et al. 1996 ** From Fromont (1993)

26m, 29.03.1993, S.D. Cook on FV 'Clipper Bird'. CRRF 0CDN1807-X (fragment QMG304797): Coral sea, atoll 145km SW of Port Moresby, outer wall north side of atoll, 10°00.66' S,145°39.90' E, 20m, 22.10.1993, CRRF/NCI.

OTHER MATERIAL. (all QM material collected by Hooper, J.N.A. and party and, all CRRF material collected by CRRF under NCI contract, unless indicated otherwise): PAPUA NEW GUINEA: CRRF 0CDN8889-V: SE of Manus, 2°12.86' S,147°13.68' E, 40m, 24.06.2003. CRRF 0CDN1944-W: Rabaul, New Britain, 4°15.90' S,152°20.45' E, 40m, 7.11.1993. CRRF 0CDN1949-C: Madang Harbor, 5°12.50' S,145°48.73' E, 18m, 10.11.1993. CRRF 0CDN8208-H: Woodlark Is., 9°13.89' S,152°25.56' E, 24m, 10.01.2002. CRRF 0CDN8463-J: Goodenough Is., Cape Vogel, 9°35.61' S,150°10.65' E, 50m, 18.01.2002. CRRF 0CDN0561-S: Barakau, 9°38.64' S,147°20.14' E, 18m, 20.10.1992. CRRF 0CDN5812-A: Louisades; Calvados Is; 11°03.09' S,152°28.62' E, 10m, 1.06.1998. CRRF 0CDN8501-Y: SE Normanby Island, 10°06.33' S,150°57.68' E, 10m, 20.01.2002. QMG312928, Kupiano, 10°11.0501' S,148°10.14' E, 20m, 15.12.1996. CRRF 0CDN5981-L: Cape Rodney, 10°15.74' S,148°23.07' E, 18m, 12.06.1998. CRRF 0CDN5760-U: Milne Bay, 10°21.59' S,150°44.75' E, 23m, 27.05.1998. QMG312951, Keppel Point, Hood Bay, 10°8.1334' S,147°54.16' E, 35m, 16.12.1996. QMG312883, Motupore Is., 9°57.0167' S,147°28.16' E, 39m, 12.12.1996, ZMA Por. 08806, precise locality not specified, M.C. Díaz, 20–30m (cross ref. no. 90113). ZMA Por 17518, Milne Bay, 10°20.4 S,150°24.7 E, 12–21m depth, 27.05.2002, R.N. Sonnenschein. SOLOMON ISLANDS: QMG322938, Jackfish Pt, Mary I., Russell Is., 9°01.10' S,158°43.77'E, 30m, 1.06.2006. VANUATU: QMG306899, Malekula Maskelyne, 16°30.05' S, 167°49.01' E, 50m, IRD/ ORSTOM Noumea (ORSTOM R1656), 14.06.1996. AUSTRALIA, QUEENSLAND, GREAT BARRIER REEF, FAR NORTHERN SECTOR: QMG300293, Cockburn Is., 12°04.99'S, 143°18.99'E,11m, 11.12.1990. NTM Z004033, Cockburn Is., 12°05' S,143°19.01' E, 17m, 11.12.1990, NTM Z004042, Blanchard Reef, 13°23.3834' S,143°44.39' E, 14m, 12.12.1990. QMG320579, G320597: Wilson Reef, 13°40.3579' S,144°13.6' E, 36m, 1.07.2003. QMG320491, The Gut Rodder Reef, 13°54.787' S,144°21.22' E, 25m, 29.06.2003. CAIRNS–COOKTOWN SECTOR: QMG304310 Day Reef, 14°28.0667' S, 145°31.04' E, 25m, 7.04.1994. NTM Z004046, Howick Is., 14°29.55' S,144°58.54' E, 20m, 14.12.1990. QMG304178, Lizard Is., 14°39' S,145°27' E, 18m, 4.04.1994. NTM Z004062, Lizard Is., 14°40.0001' S,145°27' E, 15m, 17.12.1990. QMG304413, Lizard Is., 14°42' S,145°27.14' E, 15m, 11.04.1994. QMG305136, South Direction Is., 14°49.1501' S,145°31.15' E, 15m, 28.02.1995, QMG319070, Ribbon Reef No7, 15°08.164' S,145°43.75' E, 29m, 24.11.2001. QMG319054, Harrier Reef, 15°08.1971' S,145°41.3' E, 22m, 23.11.2001. QMG307657: Low Isles Sand Cay, 16°23.0501' S,145°33.04' E, 9m, 15.01.1997. QMG307714, Wooded Islet, Low Isles, 16°23.1334' S,145°34.02' E, 15m, 16.01.1997. QMG319560, NE of Cape Grafton, 16°43.911' S,146°06.85' E, 22m, 11.02.2002. QMG319151, Cape Tribulation, 16°06.5541' S,145°38.63' E, 16m, 25.11.2001. QMG321844, Fitzroy Is., 16°55.59'S, 145°59.29' E, 20m, 24.11.2004. QMG321866, Normanby Is., 17°12.24' S, 146°04.45' E, 13m, 25.11.2004. QMG321893, Gibson Reef, 17°18.35' S, 146°20.65' E, 24m, 26.11.2004. QMG321952, Hall-Thompson Reef, 17°36.58' S, 146°26.51' E, 15m, 26.11.2004. QMG322002, Potter Reef, 17°44.59' S, 146°29.32' E, 22m, 27.11.2004. QMG322051, Farquharson Reef, 17°46.80' S, 146°28.66' E, 25m, 28.11.2004. TOWNSVILLE–WHITSUNDAY SECTOR: NTM Z002739, Myrmidon Reef, 18°10.0001' S,147°23' E, 15m, 1.01.1985, C.R.Wilkinson, QMG314345, Curacao Is., Palm Is., 18°40.825' S,146°32.63' E, 30m, 22.01.1999. QMG314448, Davies Reef, 18°49.555' S,147°37.57' E, 24m, 24.01.1999. QMG314550, Stanley Reef, 19°18.83' S,148°02.56' E, 30m, 25.01.1999. QMG314985, Hook-Hardy Reefs, 19°45.229' S,149°10.76' E, 26.7m, 5.06.1999. QMG303891, Hook Reef, 19°49.0167' S,149°06.09' E, 31m, 10.12.1993. QMG303845, Hook Reef, 19°49.0334' S,149°07.02' E, 21m, 8.12.1993. QMG315282, Round Reef, 19°57.6441' S,149°37.28' E, 20m, 6.06.1999. QMG314807: Hook Is., 20°03.93' S, 149°55.41' E, 15m, 3.06.1999. QMG314912, Cateran Bay, Border Is., 20°09.15' S, 149°02.54' E, 30m, 4.06.1999. QMG314939, Haslewood Is., 20°17.34' S, 149°04.45' E, 25.8m, 4.06.1999. QMG315320, Edgell Reef, 20°08.88' S, 149°55.15' E, 18 m, 6.06.1999. QMG315366, Stevens Reef, 20°32.57' S, 150°06.43' E, 30m, 7.06.1999. QMG315439, Chauvel Reef, 20°49.54' S, 150°20.13' E, 19m, 7.06.1999. MACKAY–CAPRICORN SECTOR: QMG315604, Coral Gardens, Heron Is., 23°27.0' S, 151°53.99' E, 10m, 5.06.1999, Garson M. and party. QMG321661, Heron Is., 23°26.48' S, 151°53.68' E, 30.2m, 10.11.2004. QMG307184, Heron Is., 23°27.08' S, 151°54.12' E, 25m, 6.08.1996. QMG307221, G307222, Sykes Reef, 23°25.13' S, 152°03.03' E, 25m, 7.08.1996. QMG307281, Snow's Point, Heron Is., , 23°28.02' S, 151°56.05' E, 25m, 7.08.1996. QMG307498, Polmaise Reef, 23°33.05' S, 151°39.15' E, 12m, 12.08.1996. QMG307600, Heron Is., Wistari Reef Channel, 23°26.08' S, 151°53.10' E, 20m, 13.08.1996. QMG314073, Lady Musgrave Is., 23°53.32' S, 152°25.6' E, 21m, 22.02.1998. QMG305503, Price Cay, Swain Reefs, 21°47.08' S, 152°27.02' E, 30m, 25.07.1995. QMG305547: Price Cay, Swain Reefs, 21°47.08' S, 152°27.07' E, 30m, 26.07.1995. QMG305600, Frigate Cay, Swain Reefs, 21°44.08' S, 152°25.03' E, 32m, 27.07.1995. QMG317433, Surprise Reef, Swain Reefs, 21°59.15' S, 152°20.71' E, 30m, 5.02.2001. QMG317626, Reef 21-490, Swain Reefs, 21°36.31' S, 152°22.19' E, 17m, 8.02.2001. QMG317734, Star Reef, Swain Reefs, 21°30.0' S, 152°26.14' E, 30m, 11.02.2001. QMG317782, Reef 21-484, Swain Reefs, 21°34.61'

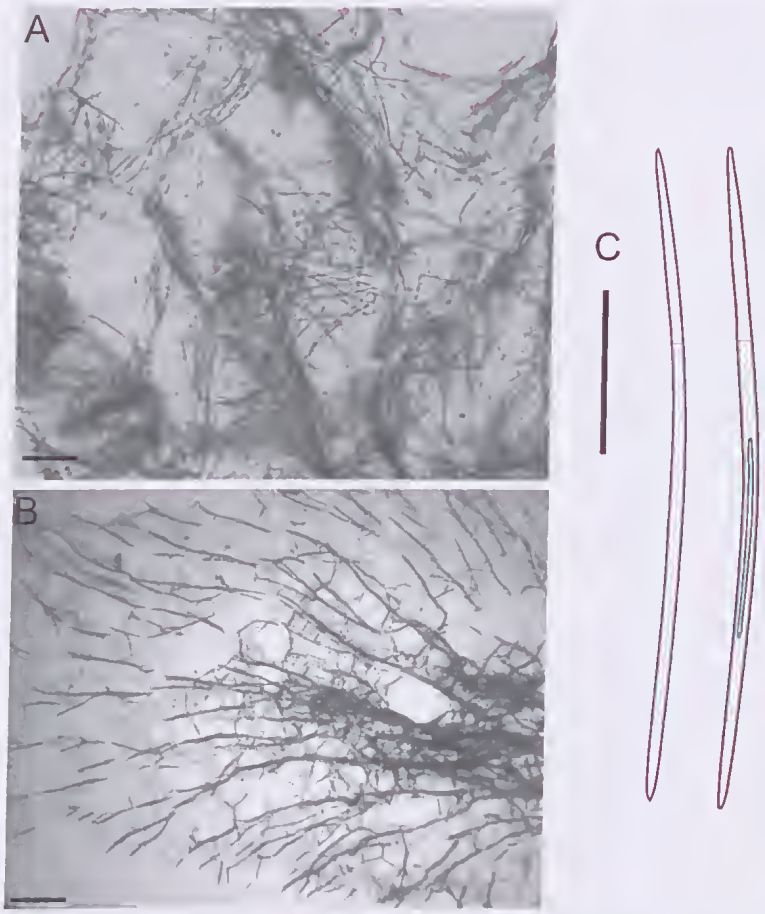

FIG. 2. *Pipestela candelabra* sp. nov. A, light micrograph of skeleton (Holotype, QMG320790, scale 100 µm). B, light micrograph of skeleton (OCDN 0561-S, scale 500 µm). C, diagram of oxeas (scale 50 µm).

S, 152°22.82' E, 30m, 11.02.2001. QMG317822, Capricorn Reef, Swains Reef, 21°45.73' S, 152°10.84' E, 14m, 12.02.2001. QMG318035, northern Swain Reefs, 21°42.35' S, 151°44.53' E, 10.4m, 11 Mar, 2000. QMG314664, South Percy Is., 21°44.18' S, 150°19.17' E, 4.5m, 1.06.1999. QMG315481, Pompey Reefs, 21°29.74' S, 151°09.80' E, 26.2m, 8.06.1999. QMG318376, Pompey Reef, 21°12.75' S, 151°11.72' E, 21.8m, 18.03.2000. QMG318081, Rene's Nook, T Line Reefs, 21°17.96' S, 151°31.49' E, 28m, 13.03.2000. QMG318224, Hard Line Reefs, 21°02/41' S, 151°28.85' E, 24m, 15.03.2000. QMG318250, Hard Line Reefs, 20°57.75' S, 151°18.08' E, 30m, 16.03.2000. QMG318313, Hard Line Reefs, 20°50.13' S, 151°09.74' E, 23.6m, 17.03.2000. QMG320004, G320029, Keppel Is., 23°09.55' S, 151°04.23' E, 17.6m, 4.11.2002. QMG320057: Keppel Is., 23°03.98' S, 150°57.17' E, 15.8m, 5.11.2002. QMG320114, Keppel Is., 23°07.08' S, 150°59.45' E, 17.4m, 6.11.2002.

CORAL SEA TERRITORIES: QMG306611, Wreck Reef, 22°10.78' S, 155°11.47' E, 30m, 15.01.1996.

DESCRIPTION. *Morphology.* Erect, 15–40cm tall on solid stalk of variable length and diameter. Growth form is arboreseent, with eylindrieal branehes, lobes, hollow digits or tubes, 0.5–3em in diameter, with walls of 3–5mm thiek, with or without bulbous swellings along longitudinal length; sometimes fused together into a lamellar mass (Fig. 1A–D).

Colour. Orange, yellow or tan alive, yellow-beige in ethanol.

Oscula. Apieal, single, large, conspicuous, on ends of tubes and on side or tips of branehes, 3– 5mm diameter, sometimes eovered with thin membrane

Texture. Flexible, moderately soft, velvety, rubbery, tough, not easily torn, ean be stieky

Surface ornamentation. Optieally smooth, fleshy. Slightly translueent, membranous with subdermal drainage channels

Ectosomal skeleton. Not speeialised, membranous, piereed by ehoanosomal skeletal fibres.

Choanosomal skeleton. Slightly eompressed near the axis of tubes; compressed at the stalk; with ascending and sinuous, plumose- paueimultispicular ill-defined fibres, eored by oxeas (not occupying all of fibre diameter). Fibres either anastamosing or eonneeted by single spicules or paueispicular short fibres at more or less regular intervals. Near-surfaee fibres beeome wispy. Interstitial free spieules abundant. Moderately heavy eollagen present in mesohyl (Fig. 2A–B).

Spicules. Oxeas or strongyloxeas, thin (164–352 µm x 2–6 µm); some almost vestigial, eurved, slightly bent, or sinuous, in a single size category

(Table 1); with axial channel occupying 10–90% of the total length frequently visible. Tips of oxeas are hastate, fusiform, or evenly rounded (Fig. 2C). Less frequent styles present in some specimens in the same size range. No microscleres

HABITAT. The species is generally found growing on slopes, walls, overhangs or caves of coral reefs in clear water (10–30m visibility), between 4.5–50m deep.

DISTRIBUTION. Papua New Guinea, Solomon Islands, Vanuatu, Coral Sea Territories and Great Barrier Reef, Australia (Fig. 3). This species is one of the most widely distributed sponges along the length and breadth of the GBR, from the coast to the outer barrier reefs, from near Torres Strait to the southern most reefs of the GBR. It is relatively common in some areas but mostly restricted to deeper waters (15–20m on reefs), and only rarely above about 10m depth.

ETYMOLOGY. The species is named according to a colloquial name used by the Coral Reef Research Foundation ('*Candelabra sponge*') to identify the species during their collections for the U.S. National Cancer Institute. It is used as a noun in apposition.

REMARKS. The present species is nominated as the type species of the genus with a predominant growth form of tubes or cylindrical projections on a stalk. A similar growth form is found in species of the axinellid genus *Auletta*, but in that genus the choanosomal skeleton is reticulated and constructed by thick tracts of robust sinuous strongyles, styles and oxeas. Conversely, the skeleton of *P. candelabra* is a loose reticulation of wavy tracts of thin oxeas embedded in a spongin sheath or ill-defined fibres. In this respect the species might be related to *Cymbastela* which shares the possession of oxeas as the only type of spicule in the skeleton. *Cymbastela*, however, is typically cup-shape, also on a short stalk as in *Pipestela*, but never with cylindrical branches or 'real' tubes (not the tube-like projections, which are in fact cups within cups, commonly observed in some individuals of *Cymbastela*). The skeleton of *Cymbastela* spp is robust with a high spicular content giving the sponge a tougher and nearly incompressible consistency quite instead soft and low in spicule content as seen in *Pipestela*). The oxeas in species of *Cymbastela* are on average thicker (3.2–14.4 µm, Hooper and Bergquist, 1992) than the present species (2.4–7.1 µm; see Table 1). Some individuals (e.g. QMG312951, QMG307657) of *P. candelabra* however, have spicules of similar thickness when compared to

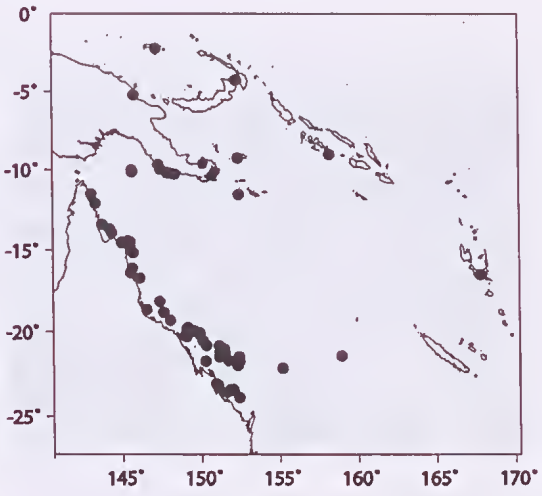

FIG. 3. Distribution of *Pipestela candelabra* based on all records from QM and NTM.

Cymbastela spp. Changes in spicule thickness however, could be related to the availability of silica in the environment (Kelly-Borges & Vacelet, 1995) thus this character, although quite consistent through the examined specimens, cannot be considered a diagnostic indicator to separate species of these genera. Some specimens collected in Papua New Guinea (ZMA Por. 07892, ZMA Por. 10892) are also very similar to *P. candelabra* in growth form and external features and were found to have overlapping skeletal characters typical of *Axinella* (e.g. skeleton differentiated in axial and extra-axial regions and a presence of styles-subtylostyles with rounded ends) indicating that external shape of this species can be repeated at least in two other genera of Axinellidae (see Discussion below).

Records of this species under the name *Auletta constricta* (see synonymy) are based on the misinterpretation of Pulitzer-Finali's (1982) brief description and sparse illustrations. Re-examination of the holotype (MSNG 46930), collected from the Great Barrier Reef, shows that this record does not agree with *Pipestela candelabra*. The specimen described as *A. constricta* by Pulitzer-Finali (1982), despite some resemblance in the growth form, does not agree with the definition of *Auletta*, as the skeleton is not reticulated and robust strongyles are not present. The surface, which was described as covered with acute conules up to 1mm high is also not typical of either *Pipestela* or *Auletta*. Examination of the type slide

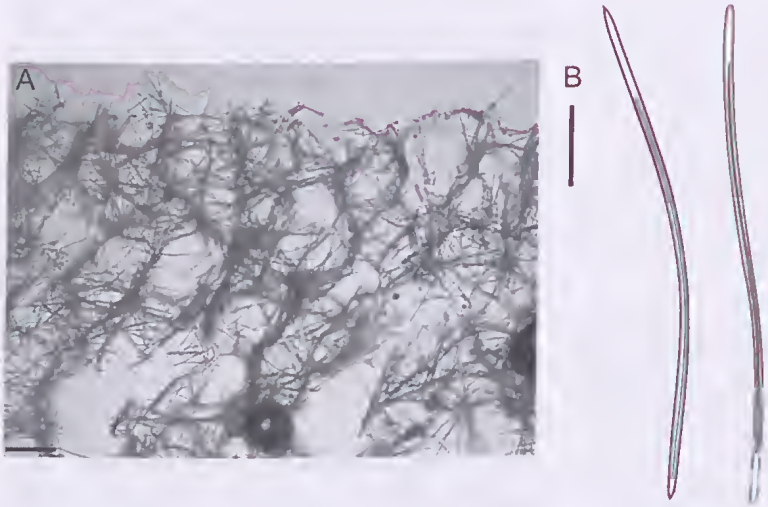

FIG. 4. *Pipestela rara* sp. nov. A, Holotype, QMG319301, light micrograph of skeleton (scale 200 µm). B, diagram of oxeas (scale 50 µm).

indicates the skeleton is mainly halichondroid, with distinct multispicular thick ascending and anastomosing tracts and abundant free spicules without any arrangement. Megascleres are slightly curved styles, in the size range reported in his publication, but the rare oxeas he mentions in his description were not found in the slide we examined. Based on the surface features, skeleton and spicule composition we here transfer it to the dictyonellid genus *Stylissa*.

Pipestela rara sp. nov
(Fig. 1E, 4)

MATERIAL EXAMINED. HOLOTYPE: QMG319301, Holmes Reef, Coral Sea Territories, Australia, 16°30.09' S,147°50.06' E, 19m, 9.02.2002, J.N.A Hooper et al.

DESCRIPTION. *Morphology.* Thickly encrusting spreading base covering dead coral, other sponges and invertebrates, with bulbous tubular fistules arising from base, predominantly fused, forming meandering ridges over the substrate. Fistules tapering at their ends forming chimneys up to 5cm high, 3cm diameter, with large apical oscule. Whole sponge up to 10cm thick in places including basal mat. The single known specimen consisted of a larger individual and a number of smaller clonal individuals in close proximity, together covering a large surface area of several square metres (Fig.1E).

Colour. Mauve-purple exterior, pinkish-beige interior alive; uniform drab brown when preserved.

Oscula. On terminal end of tubes, slightly constricted and with a thickened lip, darker in colour than the rest of the fistule or basal mat, diameter 3–6mm in life, 2–4mm when preserved.

Texture. Compressible, slightly fibrous, sticky, tearable when preserved.

Surface. Slightly honeycombed surface, smooth unornamented, with subsurface drainage canals visible in places on lateral sides of basal mat and larger fistules/ ridges, although ostia not easily seen.

Ectosomal skeleton. Membranous, with choanosomal spiculo-fibres penetrating the surface at right angles to form small brushes.

Choanosomal skeleton. More or less regular reticulation of ascending pauci- or multispicular tracts of spicules, without spongin fibres, connected by single spicules or short spicule tracts. Interstitial free spicules abundant. Mesohyl collagen light and homogenous. Some axial compression occurs further into the choanosome where the spicule tracts become less organised.

Spicules. Oxeas, flexuous, sinuous or slightly bent in one single size category, length 171.82–309.65 µm (275.48±35.59); width 2.93–6 µm (4.8±0.72). Tips of oxeas are pointy, hastate, telescoped, even or unevenly rounded, eroded or deformed; axial channel frequently visible.

HABITAT. Coral reef, 19m deep.

DISTRIBUTION. Known only from the type locality, a remote coral reef atop a 'seamount' in the Coral Sea.

ETYMOLOGY. *Rara,* Latin, feminine for *rarus* meaning scarce or hard to find and indicating the rarity of the species. It is intended to be adjectival in form.

REMARKS. The speeies differs from *Pipestela candelabra* in its growth form, eolour and surfaee charaeteristics. Both speeies have a loosely reticulated skeleton and exclusively thin oxeas as megaseleres. The skeletons of *P. candelabra* and *P. rara* are very similar but in *P. candelabra* spieule tracts are embedded in a spongin sheath forming ill-defined spongin fibres in most eases. Oxeas in *P. rara* are predominantly flexuous or sinuous with round tips. Spicule dimensions are comparable and axial ehannels are observed in the oxeas of both speeies.

Despite eomprehensive surveys of sponge faunas on the GBR and Coral Sea over the past deeade only a single speeimen of this speeies has so far been eneountered.

Pipestela hooperi
(Van Soest, Desqueyroux-Faúndez, Wright & König, 1996) comb. nov

Cymbastela hooperi Van Soest, Desqueyroux-Faúndez, Wright & König, 1996: 104.

MATERIAL EXAMINED. HOLOTYPE: MHNG 18990, Kelso Reef, Lucinda region, GBR, Queensland, Australia, 18°25'S,147°02'E, 6–9m depth, 1.03.1993, G.A.D. Wright.

REMARKS. This speeies was originally alloeated to *Cymbastela* beeause it shares with other speeies of the genus a partially lamellate growth form, tough consisteney, skeleton differentiated into axial and extra-axial regions and, type, size and teleseoped endings of the oxeotes megaseleres. Some differenees however, make the speeies atypieal of *Cymbastela*. Among these are the lamellate-flattened-enerusting habit, the unique feature of elevated oscula, and the relatively loose skeleton, formed by vaguely plumose paucispicular traets of oxeas. The latter features agree with the definition of *Pipestela* and justify the new combination here proposed.

Pipestela hooperi and *P. rara* are both known only from single individuals found in eoral reefs of the GBR and adjaeent Coral Sea Territories, and are apparently rare in both areas. The morphology reported here for *P. rara and* in Van Soest, et al. (1996) for *P. hooperi* may not therefore be representative of the 'typieal' growth forms of these species. Based on the available material the species are irregularly spreading on the substrate and laek any stalk; one growing into a modified cup- lamellate shape (*P. hooperi*) and the other into a mass of fused tubes forming ridges (*P. rara*), respeetively. Oscula in both speeies are on elevations, rounded and short in *P. hooperi*, and on larger bulbous anastomosing fistules in *P. rara*. The two species differ also in eolour, yellowish-brown in *P. hooperi* and mauve-purple in *P. rara*. The surfaee of *P. rara* has a honey-combed appearanee not found in either *P. hooperi* or *P. candelabra*. Thus, in general, the external morphology of the two speeies differs substantially from *P. candelabra* but have in common the oscula plaeed on tubular elevations although these are not well developed in *P. hooperi*.

Pipestela candelabra, *P. rara* and *P. hooperi* are very similar in skeletal structure, all with paucispieular wavy traets of exclusively thin oxeas (eneased in lightly developed spongin fibres in *P.candelabra* and *P. hooperi*), forming a loose retieulation. Other eharaeters shared by the three speeies are the presenee of abundant free interstitial spieules, the shape and dimensions of the oxeas (Table 1), with an axial canal frequently observed.

Pipestela terpenensis
(Fromont, 1993) comb. nov.

Amphimedon terpenensis Fromont, 1993: 23; Garson, 1986: 35–36; Garson et al., 1993: 1011–1014; Garson et al., 1994: 509–516; Garson & Simpson, 2004: 164–170; Simpson & Garson, 2004: 939–948.

Cymbastela terpenensis; Van Soest et al. 1996: 107.

MATERIAL EXAMINED. HOLOTYPE: QMG25039, MacGillivray Reef, Lizard Island, Cooktown region, GBR, Queensland, Australia, 14°39' S, 145°27' E, 19m, 15.10.1987, J. Fromont.

OTHER MATERIAL. AUSTRALIA, QUEENSLAND, GREAT BARRIER REEF: QMG304435, Blue Lagoon, Lizard Is., Pinnaele, bommie on E.side, 14°42' S,145°27.14' E, 15m, 11.04.1994, J.N.A. Hooper et al. QMG304168, Turtle Beach, Lizard Is., headland N.side of bay, 14°39.0167' S,145°27' E, 15m, 4.04.1994, J.N.A. Hooper et al. QMG305393, Gannet Cay, S side reef, fore-reef slope, Swain Rfs, 21°59.0833 S,152°28.1'E, 24m, 23.07.1995, J.N.A. Hooper et al. NTM Z003170, Blue Lagoon, Lizard Is., Cairns region, 14°40.0001' S,145°28.01' E, 20m, 1.01.1987, A.W.D Larkum *et al.* NTM Z004037, W side of Nomad Reef, near Mason Is., Cockburn Is., Cape York region, 12°4.6001' S,143°18.8' E, 17m, 11.12.1990, J.N.A. Hooper. NTM Z004057, Blue Lagoon, Lizard Is., Cairns region, 14°40.0001' S,145°27' E, 15m, 17.12.1990, J.N.A. Hooper.

DISTRIBUTION. The speeies appears to be restrieted to the GBR and overlaps with the distribution of other speeies of *Pipestela* (Fig. 5). It is found in eoral reef habitats throughout the GBR, from Torres Strait to Masthead Island in the southern Bunker Group, and from eoastal

waters to the outer barrier reefs (QM database). It is more commonly found in lagoons and more sheltered waters where it has been found to grow to a reasonably large size (Fig. 1F), and its depth distribution is similar to that of *P. candelabra*.

REMARKS. This problematic species was originally thought to be related to the haplosclerid genus *Amphimedon* in the family Niphatidae. Although some features of the skeleton resemble members of that family, the absence of a proper tangential ectosomal skeleton is not in agreement with the diagnosis of *Amphimedon*. Based on this and other characteristics, such as the organisation of the choanosomal skeleton, the dimensions of the spicules, and chemical features (i.e. presence of isonitriles not previously recorded in other members of Haplosclerida, and an atypical chemical structure of fatty acids) Van Soest et al. (1996) transferred the species to the axinellid genus *Cymbastela*, with some hesitation as it differed from other species of that genus. Nevertheless, *A. terpenensis* was hypothesised to be related to *C. hooperi* (here also transferred to *Pipestela*), based on the common features of the loose structure of the choanosomal skeletons and the presence of isonitriles. This further supports the creation of a new genus to accommodate these species which were not typical of the homogeneous genus *Cymbastela*.

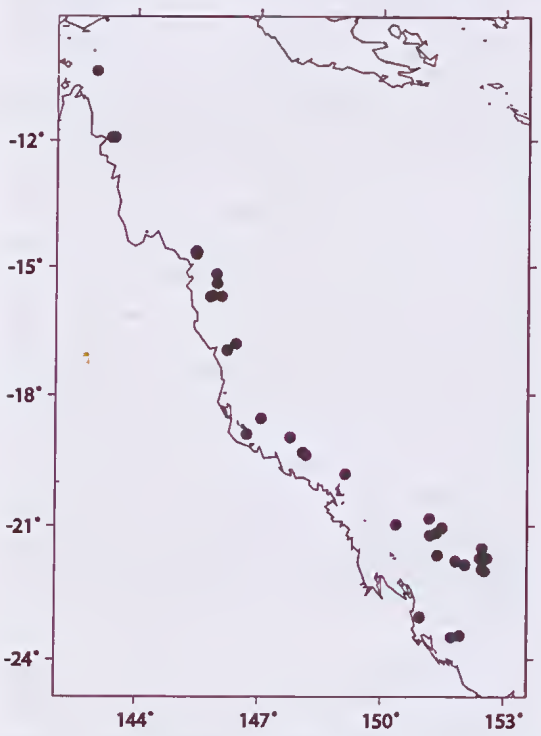

FIG. 5. Distribution of *P. terpenensis* based on all records from QM and NTM.

This species was described by Fromont (1993) as tall erect lamellate and/or coalescing branches with the appearance of flattened organ pipes, a feature that is vaguely reminiscent of *Pipestela candelabra* and *P. rara*. The colour is red-brown alive with cyanobacterial symbionts. Oscula are 2mm in diameter and located on the edges, raised ridges and nodes of the sponge. Skeleton is reticulated with paucispicular ascending tracts, encased in lightly developed spongin fibres and connected by short tracts and ending in narrow fans at surface. Spicules are exclusively oxeas, curved with fusiform or round tips and most with axial channel. All these features were confirmed in additional specimens examined here and agree with the definition of *Pipestela*.

Pipestela terpenensis produces large amounts of terpenes and its chemistry has been studied extensively (Garson et al., 1993; Garson et al., 1994; Garson & Simpson, 2004; Simpson & Garson, 2004).

Pipestela occidentalis sp. nov.
(Fig. 6)

MATERIAL EXAMINED. HOLOTYPE: WAM Z27509, 50m from shore, west side of Barrow Island, Cape Poivre, Western Australia, 20°48.1' S,115°19.5' E, 25m, 26.08.1988, D. Low Choy and NCI group (fragment NTM Z003366).

DESCRIPTION. *External morphology*. Erect, arborescent, stalked; 6.8cm length, 7.9cm width; branches solid, cylindrical, anastomosing laterally or dividing dichotomously, 4–5mm diameter, with tapering or short bifurcated tips, dividing regularly on thin stalk 6.5mm diameter; 16.8mm long.

Colour. Orange alive, beige in alcohol.

Oscula. Less than 5mm diameter, on small round elevations located in single rows along the sides and around the tips of the branches

Texture. Soft, flexible

Surface ornamentation. Smooth, microhispid perhaps velvety alive. Pierced with minute pores uniformly distributed; few branches marked with short and thin channels close to the branch tips

Ectosomal skeleton. Not specialised, pierced by choanosomal tracts.

Choanosomal skeleton. Plumose to plumo-reticulate; slightly differentiated in axial and extra-axial regions. Skeleton in axial region is halichondroid or vaguely reticulated; spongin fibres ill-defined. Extra-axial region with ascending plumose paucispicular to multispicular wavy tracts, anastomosing or connected by single spicules or short tracts, ending in brushes or fans of spicules near surface and piercing ectosome slightly.

Spicules. Oxeas, curved, fusiform; length 150.61–217.34 μm (183.8±19.74); width 3.29–5.72 μm (4.48±0.73). No microscleres.

Habitat. Coral reef

DISTRIBUTION. Western Australia. Known only from one specimen.

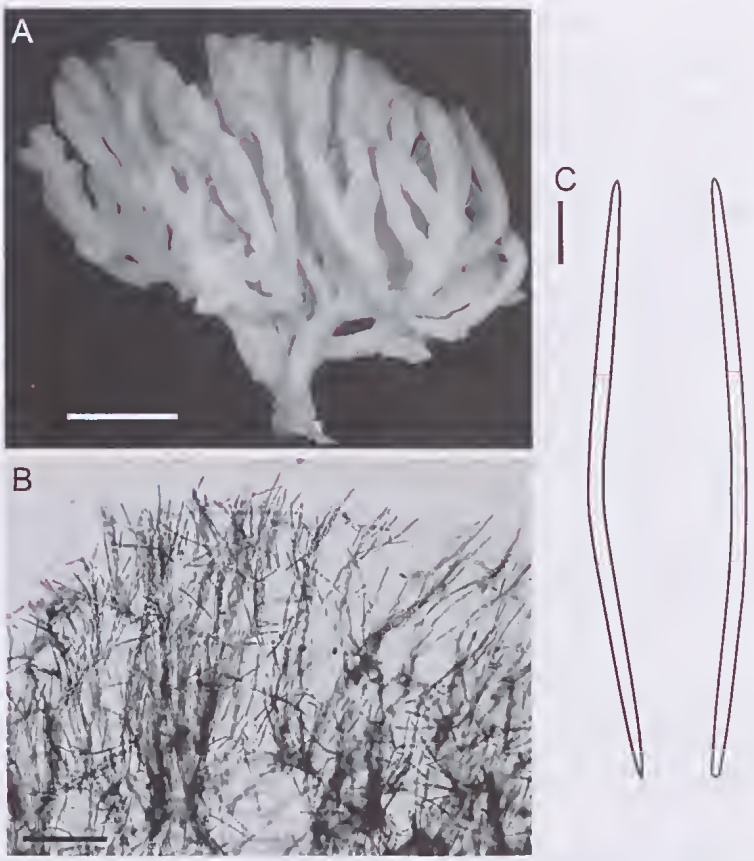

FIG. 6. *Pipestela occidentalis* sp. nov. A, Holotype, WAM Z27509, scale 2cm. B, light micrograph of skeleton (scale 200 μm). C, diagram of oxeas (scale 20 μm).

ETYMOLOGY. *Occidentalis*, Latin meaning from the west. It is intended to be adjectival in form.

REMARKS. The specimen agrees closely with *Pipestela candelabra* and it could indeed belong to this species but for its highly disjunct distribution in Western Australia, far outside the main population range of *P. candelabra*, so consequently we assign it to the genus as a new species. Disjunct distributions throughout northern Australia have been reported in numerous species of molluscs including gastropods and bivalves (e.g. Abbott, 1961; Houbrick 1978, 1992; Cernohorsky, 1991; Brunkhorst, 1993; Willan, 1993), and indeed also for several sponges, although not commonly so. The few documented examples include *Clathria (Thalysias) coppingeri*, which is mainly northwestern Australian in distribution but with rare incursions into SE Queensland (Hooper, 1996), and *Raspailia (Raspaxilla) compressa*, which was discovered on the mid-east and mid-west coasts of Australia, but not in between despite intensive benthic surveys (Hooper, 1991; Hooper & Ekins, 2004). Conversely, there are many instances of east-west coast 'sibling species pairs' that are morphologically similar but distinct species, including sponges (e.g. *Cymbastela stipitata* from NW Australia and *C. concentrica* from NE Australia, with Torres Strait being the major species turnover point (Hooper & Ekins, 2004). Consequently, we consider that a circum-tropical Australian distribution of a single morphospecies '*P. candelabra*' is inconclusive. Molecular data or other types of evidence is required to test conspecificity or otherwise between this east–west coast species pair, and also their relationships with populations of *P. candelabra* in Papua New Guinea, Solomon Islands, Vanuatu and the Coral Sea Territories.

DISCUSSION

As for other genera of Axinellidae the new genus *Pipestela* is defined by a set of morphological and skeletal characters that is not unique (i.e. these characters appear in some other genera of the family, especially *Cymbastela*, but occur in a unique combination). Species previously assigned to *Cymbastela* (i.e. *C. hooperi* and *C. terpenensis*) are transferred here to *Pipestela* based on shared characteristics with *P. candelabra*, *P. occidentalis* and *P. rara* (i.e. skeleton with a loose reticulation of plumose paucispicular tracts of relatively thin oxeas). We propose that *Cymbastela* be restricted to cup-shaped species bearing mainly robust oxeas and with a typical axinellid plumoreticulate skeleton of well-defined multispicular plumose tracts, coring well to poorly developed spongin fibres, compared with laminar, branching or tubular growth forms with a loose reticulation of mostly paucispicular tracts encased sometimes in poorly developed spongin fibres, in *Pipestela*.

Stalked and branching, thin, tubular forms similar to *Pipestela* are also found in species of *Auletta*, such as *A. sycinularia* with a type of spiculation similar to *Phakellia* and *Acanthella* (i.e. robust styles, sinuous strongyles). Other species with this type of growth form are *Auletta aurantiaca* Dendy, 1887: 92, *A. lyrata* sensu Dendy, 1905: 194, *A. lyrata glomerata* Dendy, 1905: 195, *A. lyrata crassispiculata* Dendy, 1905: 195, *A. lyrata brevispiculata* Dendy, 1905: 195 and *A. elongata* Dendy, 1905: 195. In this group of species the spicule composition consists mainly of oxeas and styles as in species of *Axinella* and the sinuous strongyles are lacking. Therefore growth form cannot be used as a diagnostic feature of these genera, especially *Pipestela* and *Auletta*.

Pipestela could potentially be confused with some haplosclerids, such as *Amphimedon*, to which *P. terpenensis* was originally allocated, but the absence of an ectosomal skeleton indicates an affinity with Halichondrida rather than Haplosclerida. The removal of this species from its original genus leaves Indo-Pacific species recognised as *Amphimedon*, as a more cohesive group characterised by blue spectrum colouration and a sticky exudates. Conversely, a so far undescribed specimen collected in Oman (ZMA Por. 13896) has many of the diagnostic features of *Pipestela*, including the tubular branching growth form, choanosomal skeleton and spicule composition and dimensions, but also has a tangential ectosomal skeleton characteristic of *Amphimedon*, indicating that might better be allocated to that genus. Assuming that the diagnostic morphological characters proposed for *Pipestela* are plesiomorphic, its affinities with members of Axinellidae become uncertain and phylogenetic studies using appropriate genetic markers (Alvarez, in progress) are required to confirm the position of the new genus in the sponge classification.

A variety of novel chemical compounds have been discovered from *Pipestela* species. *Pipestela candelabra* produces at least three types of milnamide (A-C), a novel compound with toxic cytoskeletal activity (e.g. microtubule depolymerization, microfilament disruption) (Sonnenschein et al., 2004). *Pipestela terpenensis* and *P. hooperi* produce sesqui- or diterpenes derived from isonitriles of similar chemical structure (e.g. di-iso-cyano-adociane). Other isonitrile derivates have been isolated from halichondrid sponges but not from haplosclerids (Van Soest et al., 1996b and references within), supporting the allocation of this new genus to the Axinellidae in Halichondrida.

Extensive collection records of *Pipestela* species indicate that the genus is distributed mainly throughout northeastern Australasia, extending from the southern GBR to northeastern PNG, the Australian Coral Sea Territories, the Solomon Is and also one record in central Vanuatu, and its species are always associated with coral reefs in relatively clear water. The absence of *Pipestela* in the characteristically more turbid waters of Arafura and Timor Seas, and its reappearance in northwestern Australia (albeit indicated so far by only a single specimen found off the coast of Western Australia which closely resembles *P. candelabra*), supports the hypothesis that these sponges are not generalists but niche specialists, surviving only in clear water coral reef habitats (e.g. Hooper, 1994), and thus potentially having a much broader distribution across the Indo-west Pacific than is presently known. Molecular studies are needed to determine the precise affinities of the material collected from Western Australia, and further effort is required to search for additional outlying populations either side of the known range to precisely define the distribution limits of both *P. candelabra* and the general distribution of the genus.

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A NEW SPECIES AND FIRST RECORD OF *DILATOPS* WEIRAUCH (INSECTA: HETEROPTERA: MIRIDAE: PHYLINAE) FROM NEW CALEDONIA

GERASIMOS CASSIS AND CHRISTIANE WEIRAUCH

Cassis, B. & Weirauch, C. 2008 04 30. A new species and first record of *Dilatops* Weirach (Insecta: Heteroptera: Miridae: Phylinae) from New Caledonia. *Memoirs of the Queensland Museum* **52**(2): 119–122. Brisbane. ISSN 0079-8835.

A new species of the leucophoropterine genus *Dilatops* Weirauch (Insecta: Heteroptera: Miridae: Phylinae), *D. monteithi* sp. nov., is described from New Caledonia. The species is illustrated, including features of the male genitalia. Comparisons are made with the type species *Dilatops fici* Weirauch and species of the genus *Lasiolabops* Schuh. ❐ *Heteroptera, Miridae, Phylinae, Leucophoropterini, Dilatops, new species, New Caledonia*

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Weirauch (2006) described a new genus of leucophoropterine, *Dilatops* Weirauch (Miridae: Phylinae), from Australia. The type species, *D. fici* Weirauch, is noteworthy because of its host plant association with species of *Ficus* (Moraceae), and its broad distribution in eastern Australia. The genus is significant because of its atypical features for a Phylinae: Leucophoropterini (e.g. its S-shaped vesica), which brings into question the monophyly of the tribe, and results in a putative relationship with another annectant taxon, the Afrotropical and Oriental genus *Lasiolabops* Poppius (Weirauch, 2006). Species of this latter genus are also associated with figs.

This work is based on the discovery of an additional species of *Dilatops* from New Caledonia collected by Dr Geoff Monteith of the Queensland Museum during his ongoing inventory of the true bug fauna of the island archipelago (Monteith et al., 2006). The Heteroptera of New Caledonia have not been well documented, although for some groups, such as the Tingidae (Guilbert, 2002), the situation is improving. For the Miridae, New Caledonia is very poorly known, with few existing collections and even fewer taxonomic treatments. The New Caledonian Phylinae are represented by only seven species (Schuh, 1984, 1995); two species of Leucophoropterini (*Sejanus ansevata* Schuh and *S. novocaledonicus* Schuh) and five species of Phylini (*Campyloxnma novocaledonica* Schuh, *C. nonnueae* Schuh and *C. scleptracantha* Schuh; *Malysiaxniris couleensis* Schuh and *M. novocaledonicus* Schuh). The new species of *Dilatops* described here represents the first record of the genus and an additional species of Leucophoropterini from New Caledonia, and is part of an ongoing effort to document the species rich but largely undescribed mirid fauna of the island.

TAXONOMY

Dilatops monteithi sp. nov.
(Fig. 1)

MATERIAL. HOLOTYPE: NEW CALEDONIA, ♂, Col d'Amieu, west slope, 21°37'S 165°49'E, 7 January 2005, G Monteith, MV light, rainforest (MNHN). PARATYPES: same data as holotype, 1♂, 1♀ (AM; QM).

DIAGNOSIS. Head strongly transverse (Fig. 1A), eyes semi-stalked, extending beyond anterolateral angles of pronotum (Fig. 1A); posterior margin of head strongly excavate; body orange-brown with stramineous markings; left paramere with anterior and posterior processes of equal length, and moderately large body (Fig. 1C); right paramere lanceolate (Fig. 1D); apex of phallotheca acute (Fig. 1E); vesica S-shaped, tapered apically, apex long and slender, with secondary gonopore medial and base of vesical body short (Fig. 1F).

DESCRIPTION. Moderately large, ovoid, macropterous.

Colouration. Body mostly orange-brown, with stramineous markings. Head: dark orange-brown; genae, gula, mandibular and maxillary plates and bucculae stramineous. Antennae: AI and AII stramineous; AIII and AIV dark brown. Labium: mostly stramineous with LIV fuscous. Pronotum: mostly dark orange-brown, with broad, submedial transverse stramineous band. Proepisternum:

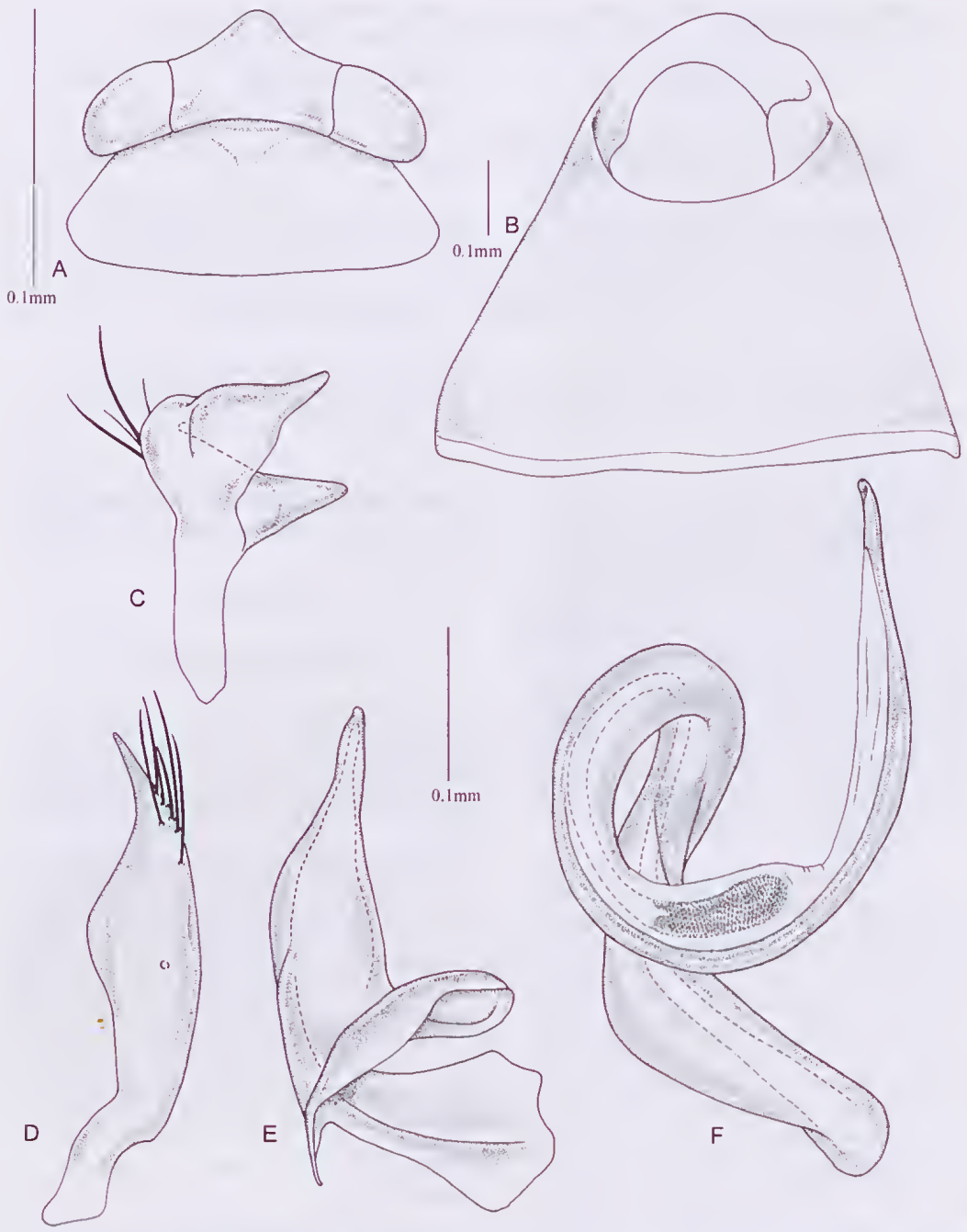

FIG. 1. *Dilatops monteithi* sp. nov. A, dorsal view of head and pronotum; B, dorsal view of pygophore; C, left paramere; D, right paramere; E, phallotheca; F, vesica.

stramineous with orange-brown highlighting. Pterothoracic pleura: dark brown, including efferent system of metathoracic glands. Mesoscutum: orange-brown. Seutellum: stramineous-brown, paler along midline and apex. Hemelytra: clavus and corium orange-brown, sometimes with weakly striped appearance; cuneus stramineous-brown, inner margins infused with red; membrane

smoky-brown. Legs: coxae bicoloured, proximally dark brown, rest stramineous; remainder of legs uniformly stramineous, sometimes with subdistal region of metafemora with red highlighting. Abdominal venter: uniformly dark brown.

Vestiture. Dorsum with uniform and dense distribution of elongate, pale, decumbent, simple setae. Abdominal venter: moderate distribution of same setae.

Texture. Impunctate, matt body; scutellum weakly rugulose.

Structure. Head: transverse (Fig. 1A), strongly declivent (clypeus not visible from above); frons + clypeus strongly tapered in anterior view; clypeus short, flat, coplanar with anterior aspect of frons; mandibular and maxillary plates small. Eyes: greatly enlarged, subpedunculate, occupying most of head in lateral view. Labium: elongate, just surpassing apices of metacoxae. Pronotum: subtrapezoidal, short, posterior margin rectilinear. Scutellum: elongate, weakly convex. Hemelytra: cuneus large. Pterothoracic pleura: metathoracic spiracle exposed, narrow, with evaporative bodies; efferent system of metathoracic glands well-developed, almost reaching mesepimeron, with semi-circular peritreme. Legs: femora fusiform; tibiae spinose. Male Genitalia. pygophore (Fig. 1B); left paramere with anterior and posterior processes of equal length, with prominent body (Fig. 1C); right paramere lanceolate with apex tapered and slightly bent (Fig. 1D), with prominent setae; phallotheca weakly sclerotised, strongly tapered apically (Fig. 1E); vesica strongly S-shaped, forming a single coil, with short base, apex very long and slender and strongly tapered, with secondary gonopore submedial (Fig. 1F). Female genitalia not examined.

DISTRIBUTION. Known only from the type locality; the western slope of the Col d'Amieu is a rainforest site. The species was collected at light and no information is known regarding its host associations.

REMARKS. This species is closely related to *Dilatops fici*, and despite the less pronounced eyes, agrees with the other diagnostic features of *Dilatops* given by Weirauch (2006). The eyes in *D. monteithi* are not as clearly pedunculate as in the type species, but they are none-the-less semistalked, with the head strongly transverse. Unlike *D. fici*, the eyes are not broader than the pronotal width across the humeral angles. In addition, the eyes in *D. monteithi* more distinctly overlap the anterior aspect of the pronotum. The heads of both species are more alike, with the frons and clypeus strongly narrowed, giving the head a pronounced triangular appearance when viewed from the front. The clypeus in both species is small, barely convex and coplanar with the adjacent areas of the frons. Other species-level differences are listed in (Table 1) and include the following character states in *D. monteithi*: i. darker colouration, being more orange-brown; iii. more medial position of the secondary gonopore of the male vesica; and, iv. anterior lobe of the left paramere less pronounced.

DISCUSSION. The Australian species, *Dilatops fici*, is found on three species of figs in eastern Australia (Weirauch 2006). In the Sydney region it is found in association with the psyllid *Mycopsylla fici* which can cause significant damage to Moreton Bay figs, *Ficus macrophylla*, in suburban parks (Froggatt, 1907; Hollis, 2004; Taylor and Carver, 1991). *Dilatops fici* has not been observed feeding, but it is possible that it preys upon the psyllid.

Dilatops monteithi has no host record, but it may also be associated with figs. *Ficus* is represented in New Caledonia by 31 species, most of which are endemic and found in rainforest (Jaffré et al., 2001). Figs are known from the Col d'Amieu site where *D. monteithi* was collected (Monteith *personal communication*) but were not intentionally sampled.

The systematic position of *D. monteithi* is a little contentious, as the species does not have strongly pedunculate eyes as found in *D. fici*. A comparison of the characters of both species of *Dilatops* and of *Lasiolabops* spp. is given in Table 1, and reveals that the two genera share features that are likely to be of phylogenetic significance. *D. monteithi*, although lacking the strongly pedunculate eyes of *D. fici*, is much more similar to that species than to any described species of *Lasiolabops*. The placement of *D. monteithi* requires a broadening of the definition of *Dilatops* to allow for the eyes to be sub-pedunculate, and the head width across the eyes to be less than the width of the pronotum across the humeral angle. This places greater importance in the characters of the vesica and left paramere in defining the genus. Beyond Weirauch's (2006) definition, the short and sub-rectangular pronotum, offers an additional diagnostic feature for *Dilatops*; the pronotum is much shorter than that found in species of *Lasiolabops*.

TABLE 1. Comparison of morphological character states of *Dilatops fici* and *D. monteithi* with *Lasiolabops* spp.

Dilatops fici	*Dilatops monteithi*	*Lasiolabops* spp.
Orange colouration	Orange-brown colouration	Dark colouration
Two types of setae	Simple setae only	Simple and adpressed setae
Eyes strongly pedunculate	Eyes sub-pedunculate	Eyes laterally produced, without pedunculate appearance
Eyes large in lateral view	Eyes large in lateral view	Eyes moderately-sized
Vertex concave	Vertex concave	Vertex flattened
Head broader than pronotum	Head subequal to pronotum	Head subequal to shorter than pronotum
Clypeus + (mandibular + maxillary plates) narrow	Clypeus + (mandibular + maxillary plates) narrow	Clypeus + (mandibular + maxillary plates) broad
Labium short	Labium elongate	Labium elongate
Pronotum short, subrectangulate	Pronotum short, subrectangulate	Pronotum more elongate, subtrapezoidal
Parempodia setiform, tapered	Parempodia setiform, tapered	Parempodia spatulate
Left paramere with dorsal lobe	Left paramere with dorsal lobe	Left paramere dorsal margin truncate
Vesica tapered, apex acute	Vesica tapered, apex acute	Vesica not tapered, apex broad
Secondary gonopore subapical	Secondary gonopore in median position	Secondary gonopore apical

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A FIELD-BASED METHOD FOR DISTINGUISHING *MELOMYS BURTONI* FROM *M. CERVINIPES* (RODENTIA: MURIDAE) IN QUEENSLAND

ANGELA FROST

FROST, A. 2008 04 30: A field-based method for distinguishing *Melomys burtoni* from *M. cervinipes* (Rodentia: Muridae) in Queensland. *Memoirs of the Queensland Museum* **52**(2): 123–126. Brisbane. ISSN 0079-8835.

Melomys burtoni and *M. cervinipes* are broadly sympatric in eastern Australia but difficult to distinguish on external criteria. Although *M. cervinipes* attains a larger size than *M. burtoni*, the two species show significant overlap in standard external measurements and reliable identification currently requires examination of a cleaned skull. The hind foot plantar pads of 20 adult individuals of each of *M. burtoni* and *M. cervinipes* were examined and found to be a consistently larger in *M. cervinipes*. ❐ *Melomys, identification, burtoni, cervinipes, foot pads.*

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The current taxonomy of Australian *Melomys* recognises a total of four species, two of which (*M. burtoni* (Ramsay) and *M. cervinipes* (Gould)) have extensive, overlapping geographic ranges in northeastern Australia (Watts & Aslin, 1981). Although *M. cervinipes* attains a larger size than *M. burtoni* (Watts & Aslin, 1981) and has a relatively shorter tail (tail length more-or-less equal to the combined length of the head and body vs tail significantly longer than the head plus body in *M. burtoni* (Watts & Aslin, 1981)), the two species show significant overlap in standard external measurements. Pelage colour is individually and regionally variable in both species (Tate, 1951) and although habitat provides a useful clue to species identification (Watts & Aslin, 1981), both species are known to occur outside their preferred habitats (closed forest for *M. cervinipes*, grassland for *M. burtoni*) (Queensland Museum records). Thus, at present, reliable morphological identification requires vouchering and examination of a cleaned skull (Keith, 1970; Knox, 1978). A method to identify the two species on external criteria would be of great use for field survey of small mammals in northeastern Australia.

Cooper (1993; 1994) described the usefulness of plantar pads on the hind foot (pes) in distinguishing sympatric and morphologically similar species of rodents in Western Australia. A key produced more recently by Metzler & Clancy (1995) described the "longitudinal" pad of the pes as curved in *M. cervinipes* and straight in *M. burtoni*. I encountered difficulties using this feature to identify Queensland *Melomys* and investigated the utility of other aspects of hind foot morphology.

MATERIALS AND METHODS

As a starting point I examined all adult spirit specimens of *M. burtoni* and *M. cervinipes* with cleaned skulls in the collection of the Queensland Museum (QM). Adult status was determined on reproductive criteria (teats obvious on females, scrotal sac prominent on males). The species identity of all specimens was validated using the diagnostic feature of the first upper molar root pattern, as described by Knox (1978). Additional spirit specimens were then selected from the QM collection to increase the sample size within the documented body size range overlap between *M. burtoni* and *M. cervinipes*, and secondarily, to ensure good coverage of the area of geographic overlap. Skulls from these specimens were removed and cleaned to confirm their identity. The final sample included 20 specimens of each species (see Table 1).

Measurements were made of pes length (from heel to base of claw on central digit), combined head plus body length (anus to tip of nose), and the length of each of the six primary plantar pads. Small accessory plantar pads are variably discrete or fused to the first and fourth interdigital pads in both *Melomys* species (Fig. 1). Measurements of these pads were designed to avoid this secondary source of variation. Measurements were taken with Mitutoyo electronic calipers and rounded to an accuracy of 0.1mm.

The length of each pad was plotted against pes length to identify the measurement giving

TABLE 1. Location of specimen, sex, hind foot length, first interdigital pad length and head-body length of *Melomys cervinipes* and *M. burtoni* used in this study. Measurements in mm.

Species	QM registration number	Sex	Location	Pes length	First interdigital pad length	Head body length
Melomys cervinipes	JM9323	M	Ayr, Barratta Ck, 3km upstream of Bruce Hwy	25.0	2.4	91
	JM11570		Cowley Bch Training area, 1.75km NNE Main Camp	25.2	2.4	101
	SEW1444			25.5	2.8	96
	JM224	F	Innisfail Common	25.4	2.7	96
	JM1383	F	Cape Hillsborough	27.3	2.7	115
	JM10991	F	Mt Inkerman	26.2	2.6	110
	JM1151	F	Crediton	24.8	2.7	93
	JM14423		Bayview Heights, Meringa	26.0	2.7	109
	JM1329	M	Caloundra	27.4	2.8	113
	JM6724		Nitchaga Bridge, 3.5km W Koombooloomba	25.3	2.9	108
	JM10593	F	Hinchinbrook Is	25.5	3.4	110
	JM1147	F	Crediton	25.2	2.7	97
	JM5274	F	Shipton's Flat	26.7	3.0	111
	JM8337		Kirrama Ra SF	26.1	2.7	101
	JM14436	M	Noosa Heads NP (western side)	27.5	3.1	126
	JM11174	M	Nambour Bypass	26.5	2.8	122
	JM5337	F	Hinchinbrook Is,Gayundah Ck	28.3	2.7	98
	JM5341	F	Hinchinbrook Is, Scraggy Pt	27.4	2.8	105
	JM1143	F	Crediton	26.7	2.9	114
	JM14361		Awoonga Dam, from Boyne Valley to Miriam Vale	25.3	3.3	97
M. burtoni	J20173	M	Mackay	25.4	1.9	112
	JM13957	M	Buthen Buthen, Nesbit Rd, McIlwraith Ra	23.6	1.8	105
	JM13559		Yabulu	24.0	1.8	111
	JM10500		Rutland Plains Hold, 11.5km NW Rankin's Well	25.9	1.2	110
	J20181		Mackay	23.9	2.0	114
	J17785	M	Mt Molloy, 3km N	24.1	1.9	94
	JM3823	F	Eurimbulah NP	25.4	1.8	97
	J20110		Mackay	24.4	1.7	100
	JM11390	M	Jenners Rd, nr Sarina	25.3	1.6	110
	JM2615	M	Kauri Ck, inlet	25.3	1.7	100
	JM3821	F	Eurimbulah NP	25.2	1.8	99
	JM12570	M	Saunders Bch, nr Townsville (Nth)	24.9	1.9	107
	J20179	M	Mackay	26.0	2.0	112
	JM1382	M	Cape Hillsborough	24.8	1.5	104
	J21856	F	Nth Stradbroke Is	25.8	2.2	97
	JM3820	M	Eurimbulah NP	27.9	1.9	123
	JM14560		Princess Hills House Dam	26.5	2.'	104
	JM14563		Princess Hill House Dam	27.4	1.9	110
	JM4267		Pine R Bay, 23km WNW Weipa, Rocky Pt	24.9	2.3	112
	J20101	F	Mackay	23.8	1.9	97

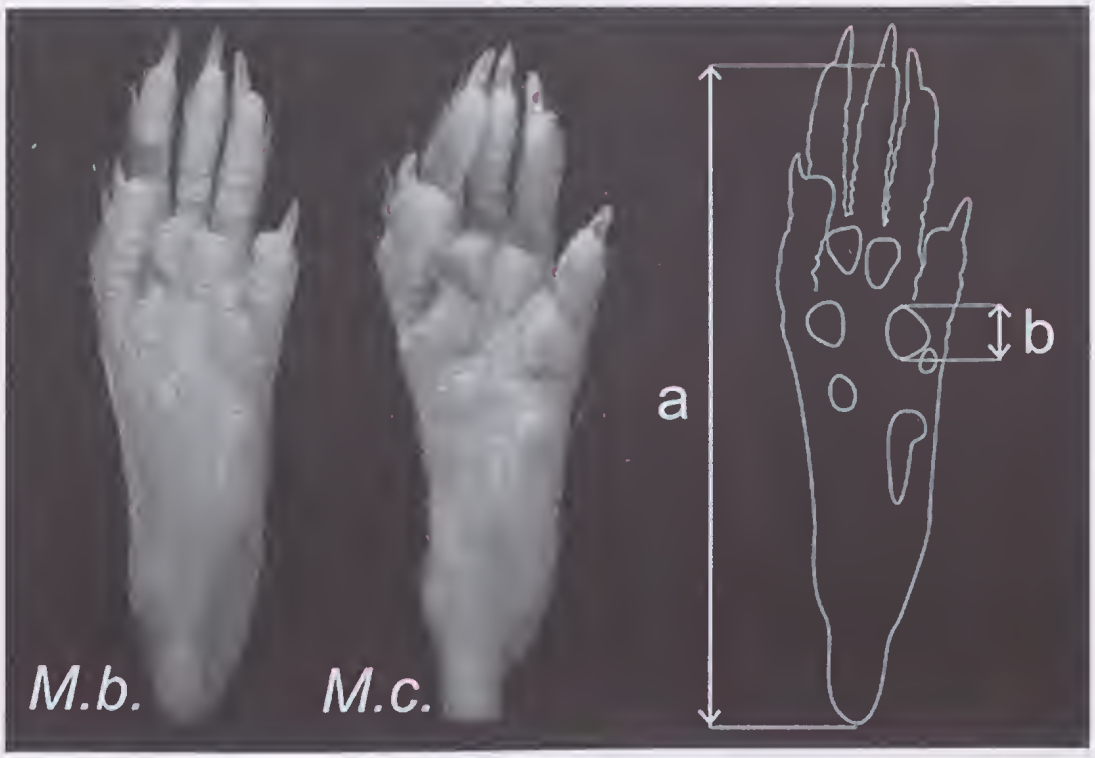

FIG. 1. Pes of A, *Melomys burtoni* and B, *M. cervinpipes* showing the relatively larger size of all plantar pads in *M. cervinipes* (plantar pads outlined in both). C, Outline of pes of *M. cervinipes* showing method of measuring total pes length (a) and the length of the first interdigital pad (b). Measurements of the first interdigital pad should be taken on the inner side of the pad to avoid the variation in the small aeeessory plantar pads whieh may be either diserete or fused. Speeimens figured are from the CSIRO ANWC wildlife eollection: A, *M. burtoni* adult male (CM16369) from Shoalwater Bay; B, *M. cervinipes* adult female (CM16349) from Shoalwater Bay, Speeies identifications based on upper molar root number, after Knox (1978).

the best diserimination. This proved to be the length of the first interdigital pad (terminology follows Brown & Yalden, 1973). The method of measurement for pes length and first interdigital pad length is indieated in Fig. 1.

RESULTS

The pes of *M. cervinipes* averages slightly longer than that in *M. burtoni* (mean ± s.d.: 26.17 ± 1.02 vs 25.22 ± 1.16; raw data in Table 1) and it also appears slightly broader for its length (Fig. 1). However, the two speeies show almost eomplete overlap in measurement ranges for pes length (24.8-28.3 vs 23.6-27.9) and any difference in width would be very diffieult to quantify.

In eontrast, foot pad size provides a reliable means of distinguishing the two speeies. As is obvious in side-by-side eomparison (Fig. 1), all of the plantar pads of *M. cervinipes* are relatively larger than those of *M. burtoni*. Measurements eonfirmed this visual impression, and further

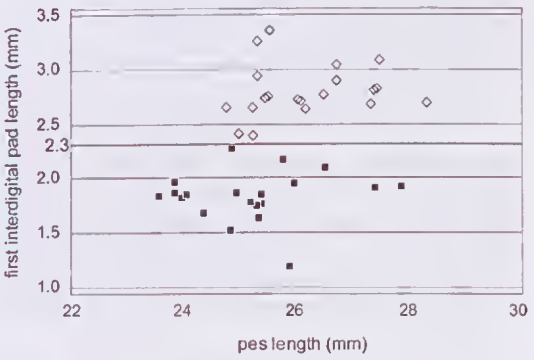

FIG. 2. Hind foot length versus first interdigital pad length in adult *M. burtoni* (solid squares) and *M. cervinipes* (open diamonds).

demonstrated that length of the first interdigital pad gave the most complete separation between the two species when plotted against pes length (Fig. 2). Importantly, length of this pad is not significantly correlated with pes length in either species, hence the single measurement appears to have diagnostic value across the full range of adult body size of both species. The cut off point appears to lie at 2.3mm—in all specimens of *M. burtoni* the first interdigital pad was shorter than 2.3mm, whilst in *M. cervinipes* this pad was consistently longer than 2.3mm.

DISCUSSION

This study has demonstrated a consistent difference in foot pad morphology between adults of *M. cervinipes* and *M. burtoni* across their area of geographic overlap, with *M. cervinipes* having measurably larger plantar pads than *M. burtoni*. Large plantar pads in murine rodents are commonly associated with scansorial or arboreal habits and the difference in pad size is consistent with the known ecological contrast between the more arboreal *M. cervinipes* and the more terrestrial *M. burtoni* (Watts & Aslin, 1981). Further studies could now extend this work to other species pairs within *Melomys*, such as *M. capensis* and *M. burtoni* that co-occur regionally on Cape York Peninsula

Although the present method appears to represent an advance over previous criteria for field identification of Australian *Melomys*, for several reasons I urge caution in its application. First, the reference series are relatively small (20 specimens per species) and did not sample the entire region of geographic overlap, e.g. sympatric populations in northern NSW were not included. Accordingly, it is likely that with more exhaustive sampling of museum specimens, some overlap in first interdigital pad length will be detected. Second, the utility of the measurement has not been tested for sub-adult and juvenile animals. Murid rodents as a group undergo significant changes in body proportions during growth from juveniles to adults, and caution must always be exercised in applying any diagnostic criterion beyond the limits of the original dataset. In the present case, it is likely that the inter-specific difference in plantar pad size develops during growth and that younger animals will show a less clear distinction.

For these reasons, I recommend that length of the first interdigital pad be added to the list of features currently used to identify eastern Australian *Melomys* (i.e. overall body size, relative tail length) and that particular care be taken to assess the individual age of a captured specimen.

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MICROMASTIGOTES SCOTTAE SP. NOV. (PARABASALIDA: SPIROTRICHONYMPHINA): A NEW TWIST ON THE HYPERMASTIGONT CONDITION.

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This study redescribes the genus *Micromastigotes*, Hollande and Carruette-Valentin, 1971, a parabasalid flagellate symbiotic in termites, on the basis of light and electron microscopy and erects a new species, *M. scottae*. The genus *Micromastigotes* is characterised by possessing flagella bands which spiral around the anterior portion of the cell, the location of the nucleus and Golgi bodies at the base of the anterior flagellated area, and an axostyle which runs the length of the cell. Individual flagella are derived from the central axis of the cell exiting perpendicularly, each is offset from the preceding flagellum by 12 — 18° thus forming a spiral band. Ultrastructurally, the flagella bases form a structure resembling a spiral staircase. Peltoaxostylar and preaxostylar fibres arise from the anterior most kinetosomes and the striated lamina forms a weakly undulating sheet directed posteriorly from each flagellum. Dense lamina and parabasal fibres are absent. *Micromastigotes* was originally classified as part of the Spirotrichonymphina and there are some similarities to other genera in this group, but *Micromastigotes* lacks a flagellar gutter, a U-shaped band at the base of the flagella composed of the striated and dense lamina, which is diagnostic of the spirotrichonymphines. The spiralisation pattern in *Micromastigotes* is not consistent with previous schemes for the development of a polymastigont condition in spirotrichonymphines suggesting that *Micromastigotes* may represent an independent derivation of a polymastigont condition from a trichomonad-like ancestor.❐ *Parabasalia, Spirotrichonymphina, Micromastigotes, Privileged-Flagella Hypothesis, Schedorhinotermes.*

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The flagellate phylum Parabasalida includes the most diverse ranges of cell structures of any protist group. Most species occur as anaerobic symbionts in a range of hosts including mammals, reptiles and birds but the greatest diversity of species occurs within termites and wood-eating cockroaches (Yamin, 1979). Much of this diversification has been associated with increases in cell size and in the complexity of the flagellar structures and their associated fibrous support organelles. The simplest parabasalids, the Trichomonadida have 3 anterior flagella and a recurrent flagellum, and this arrangement, 3 + R, forms the basis of the 'privileged flagella hypothesis' which considers that the more complex arrangements are all derived states arising by addition and elaboration of one or more of the 'privileged' elements (Brugerolle, 1991). The more complex parabasalids usually have vastly greater numbers of flagella and have been collectively classified as the Hypermastigida although this taxon is almost certainly a polyphyletic collection of groups which have independently adopted a multiflagellated or polymastigont condition (Brugerolle & Patterson, 2001). Even though molecular phylogenies of the parabasalids consistently recover the polymastigont Trichonymphidae as the earliest diverging branch of the parabasalid tree, this result is almost certainly artefactual and it should not be interpreted that the ancestral parabasalid was polymastigont (Hampl et al., 2004).

Recent molecular phylogenies of the parabasalids (Gerbod et al., 2001, 2002; Hampl et al., 2004; Keeling, 2002; Okhuma et al., 2000, 2005) have suggested that there have been up to five acquisitions of the polymastigont condition, six if Calonymphidae is polyphyletic (Gerbod et al., 2002) (Fig. 1). Four groups have been traditionally united as the Order Hypermastigia: the Trichonymphidae, Eucomonymphidae and Staurojoeninidae (collectively the Suborder Trichonymphina); the Suborder

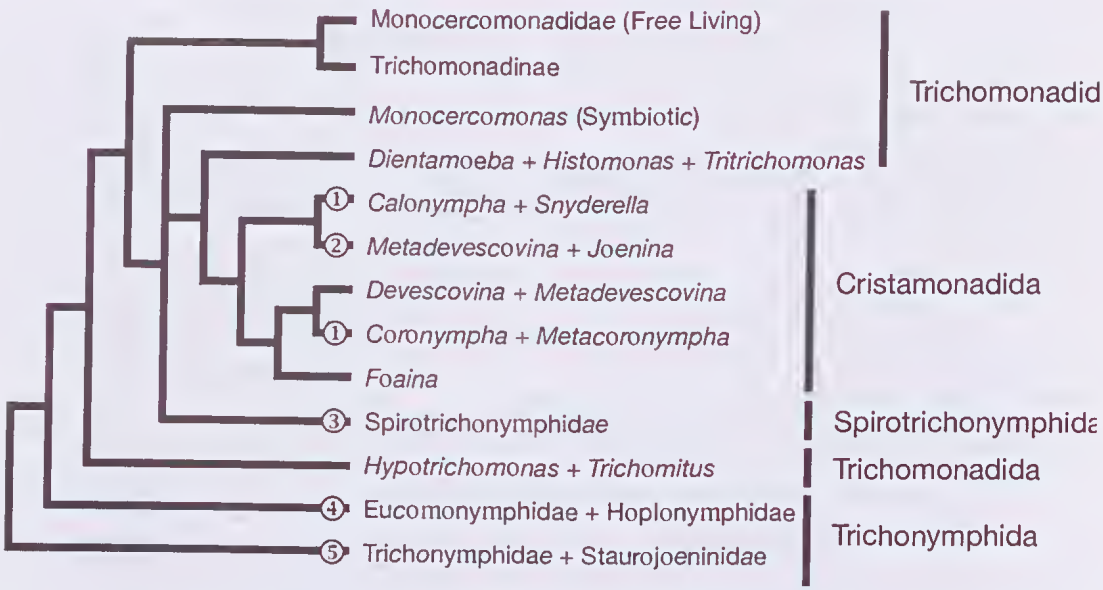

FIG. 1. Phylogeny of the Parabasalia and acquisitions of a multimastigont condition, redrawn after Gerbod et al., (2002) & Ohkuma et al. (2005). 1, Calonymphid type: replication of a karyomastigont; 2, Lophomonad type: replication of flagellum 1 into an anterior flagella plate; 3, Spirotrichonymphid type: spiral flagella bands, flagellar gutter surrounding the kinetosome base; 4, Eucomonymphid type: slightly spiralised flagella bands, each kinetosome base connected to a striated, sinusoidal root; 5, Trichonymphid type: meridional flagella bands, derived from a complex anterior rostrum.

Spirotrichonymphina (Spirotrichonymphidae) and the Suborder Lophomonadina. The fifth group, the Calonymphidae, has long been classified within the Trichomonadida but has recently been grouped with the devescovinids and lophomonads as the Order Cristamonadida on the basis of molecular phylogenies and reassessment of morphological structures (Brugerolle & Patterson, 2001). Each of these five acquisitions of the polymastigont condition has been accompanied by a distinctive subcellular architecture of tubules and fibres to support the profusion of locomotory flagella. The simplest system is seen in the calonymphids where polymastigery is achieved by simple multiplication of the privileged karyomastigont, the privileged flagella plus associated nucleus (Dolan et al., 2000a, 2000b). The simplicity of this structure and its' clear relation to flagella structure in the monomastigont devescovinids is what has lead to the grouping of calonymphids initially within Trichomonadida (Brugerolle & Lee, 2000) and more recently within Cristamonadida (Brugerolle & Patterson, 2001). Even if the calonymphids are polyphyletic as suggested by Gerbod et al. (2002), the two calonymphid groups have both achieved the polymastigont condition in the same way, by replication of the karyomastigont, and constitute an example of parallel evolution (Dolan et al., 2000a, 2000b; Dolan & Kirby, 2002). The lophomonads also retain the privileged flagella and the polymastigont condition is achieved by vast replication of flagellum 1 into an anterior flagella plate (Brugerolle & Patterson, 2001; Brugerolle & Bordereau, 2003). More complex arrangements which are less readily interpreted in terms of modification of the privileged flagella occur in the other three groups. Eucomonymphids are characterised by their flagella being grouped into slightly spiralised, longitudinal rows and each flagellum possesses a striated, sinusoidal microtubular root which was termed the parabasal filament by Hollande & Carruette-Valentin (1971) although its relationship to the parabasal filament of trichomonads is unclear (cf. Brugerolle, 1999, 2000; Cameron & O'Donoghue, 2003). Trichonymphids have a very complex anterior rostrum from which meridional lines of flagella arise, the rostrum itself is a very complex structure with multiple interacting layers of fibrils (Hollande & Carruette-Valentin, 1971). Spirotrichonymphina, as the name suggests, have spiral rows of flagella radiating from the anterior end, each row has as its base a structure termed the 'gutter of the flagella band' by Brugerolle (2001) composed

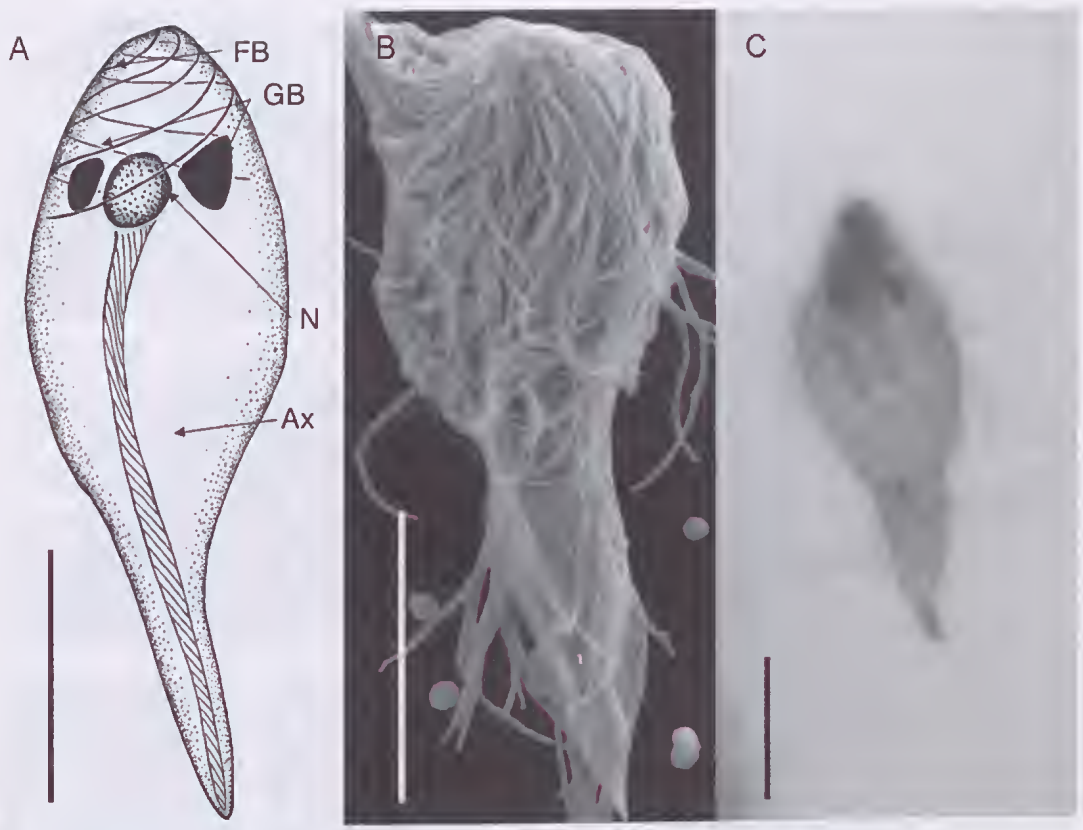

FIG. 2. Morphology of *Micromastigotes scottae* sp. nov. A, Line diagram. B, Scanning electron micrograph. C, Light micrograph of protargol stained specimen. Scale bars = 10 µm. Ax, axostyle; FB, flagella band; GB: Golgi body; N, nucleus.

of outer dense lamina and an inner striated lamina. The flagellar gutter thus has the form of a U-shaped ribbon spiraling around the cell close to the base of the kinetosomes. This arrangement occurs in the widespread and speciose genera of spirotrichonymphines, *Spirotrichonympha* and *Holomastigotoides* (Brugerolle, 2001; Lingle & Salisbury, 1995) but variations occur in the simpler genera *Microjoenia*, *Spirotrichonymphella* and *Micromastigotes* Hollande & Carruette-Valentin (Brugerolle, 2001; Hollande & Carruette-Valentin, 1971). In *Microjoenia*, the flagellar gutter is poorly formed, the dense and striated lamina being frequently separated and not forming a continuous ribbon connecting adjacent kinetosomes (Brugerolle, 2001). The flagella of *Spirotrichonymphella* are derived from a central core or columella, each flagellum is connected to the columnella by a pair of striated roots, internal to the striated roots is a striated lamina which spirals downward to follow the path of the flagella band (Brugerolle, 2001; SLC pers observ.). *Micromastigotes* apparently has the simplest morphology of all; the flagella are apparently derived directly from a central core, axial within the cell and in the description by Hollande & Carruette-Valentin (1971), lacking both striated roots and the striated lamina. The possibility that *Micromastigotes* represents the simplest spirotrichonymphine led us to undertake a complete redescription of the genus and a detailed study of its flagella structures following the discovery of a new species of this genus in the northern Australian pest termite species *Schedorhinotermes intermedius*.

MATERIALS AND METHODS

Thirteen colonies of *Schedorhinotermes intermedius* were collected from southeastern Queensland (QLD) Australia, from Joyner (3 colonies), Deception Bay (1), Samsonvale (3), Samford (4), Ferny Hills (1) and Moggill Creek (1). Colonies were collected from under

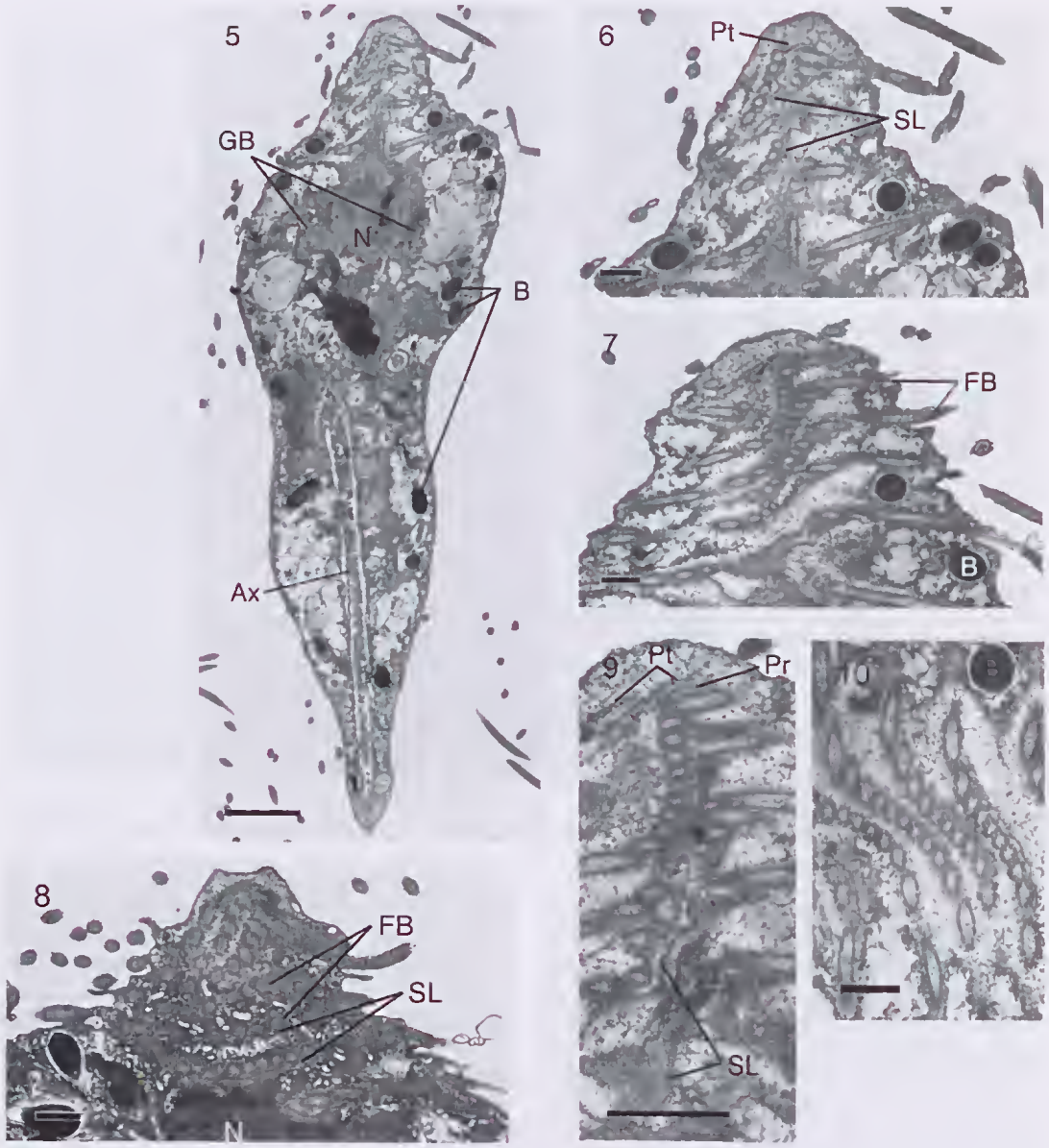

FIG. 3. *Ultrastructure* of *Micromastigotes scottae* sp. nov. A, Longitudinal section, whole cell; B–D, Serial longitudinal sections through a single cell from axial plane (6) to peripheral plane (8); E–F, Anterior mastigont system. Scale bars: 5: 2 µm; 6-8: 500 nm; 9: 1 µm; 10: 500 nm. Ax: Axostyle; B: Bacteria; FB: Flagella bands; GB: Golgi body; Pr: Preaxostyle; Pt: Peltoaxostyle; SL: Striated Lamina.

fallen timber, within dead fallen branches and from within tubular galleries within the bark of living trees. Individual termites representing the worker, major soldier and minor soldier castes were collected from each colony. Voucher collections were made of each colony by preserving five of each caste in 70% ethanol which were used to identify the termite species collected. Nest material was collected along with termites and each colony was provided with tissue paper soaked in water as a moisture and food source to maintain the colony in the laboratory. Workers were examined shortly after collection by dissecting the hindgut

into a small drop of invertebrate saline (0.6% NaCl). Some workers were removed directly from the nest and examined, these are referred to as 'dirty' specimens. 'Cleaned' specimens were generated by isolating individual workers from nest material and then rearing them on water-soaked tissue paper for several days to purge them of dirt and coarse wood fibres in their guts.

Light microscopic observations were performed on Giemsa-stained and protargol-impregnated specimens. Giemsa staining was performed on partially air-dried smears fixed with methanol. Slides were examined without coverslips by bright-field microscopy under immersion oil. Specimens from both 'cleaned' and 'dirty' termites were prepared for light microscopy to determine if cleaning caused artefactual changes to the flagellates. Protargol impregnation was performed according to the method of Foissner (1991) on specimens fixed with Schaudin's fluid. Cells were drawn using a camera lucida, and measured in each dimension using a calibrated eye-piece micrometer. Measurements are presented as a range of values followed by the average in parentheses.

Specimens for electron microscopy were collected exclusively from 'cleaned' termites dissected into Locke's fluid (composition in mM: 136 NaCl, 5.6 KCl, 1.2 MgCl2, 2.2 CaCl2, 1.2 NaH2PO4, 14.3 NaHCO3 and 10 dextrose, final pH 7.3–7.4) and fixed in a vast excess, typically at least 10 volumes, of 3% glutaraldehyde in 0.066M cacodylate buffer (pH 7.2) for 30 min. Cells for scanning electron microscopy were washed in 0.1M cacodylate buffer for 1 hour, post-fixed with 1% osmium tetroxide in 1.5% potassium ferricyanide for 1 hour, washed three times in distilled water and stored in 70% ethanol. Specimens were dehydrated in a graded series of ethanol solutions (80%, 90%, 100%, 100%) for 10 min each. Samples were critical point dried in CO2 between 8nm polycarbonate filters in a Millipore Swinnex filter holder. Dried samples were mounted on stubs with double sided tape, sputter coated with platinum and examined in a JOEL 6400 scanning electron microscope. For transmission electron microscopy, fixed samples from several termites were pooled and washed three times in Soerenson's phosphate buffer (pH 6.8) for 30 min each. Cells were post-fixed in 4% osmium tetroxide for 1 hour and washed three times in distilled water (10 min., 10 min. and overnight). Specimens were then dehydrated in a graded series of acetone solutions (5%, 10%, 15%, 20%, 25%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 100%, 100%) for 10 min each. Cells were gradually infiltrated with Epon resin (25%, 50%, 75% Epon in 100% acetone for 1 hour each, 100% Epon overnight) and embedded in fresh 100% Epon, pelleted by gentle centrifugation and cured for 1 day at 60°C. Semi-thin survey sections were cut with glass knives, stained with 1% toluidine blue and used to orientate sections. Ultra-thin sections (70 nm and 90 nm) were cut with diamond knives, mounted on formvar-coated copper slot grids, stained with 5% uranyl acetate in 50% methanol for 2 min., washed in distilled water for 30 sec. and dried. The sections were then counter stained with Reynold's lead solution (2% lead citrate) for 1 min., washed in distilled water for 30 sec. and dried prior to examination. Sections were examined in a JEOL 1010 transmission electron microscope.

RESULTS

The soldiers and workers from 5 of the 13 colonies (38%) were found to harbour a small hypermastigid flagellate belonging to the genus *Micromastigotes* in addition to other parabasalid flagellate species. This *Micromastigotes* species appeared to be novel and its morphology and ultrastructure are described below.

Micromastigotes scottae sp. nov.

TYPE HOST. *Schedorhinotermes intermedius* (Isoptera: Rhinotermitidae)

HABITAT. Termite hindgut

TYPE LOCALITY. by Moggill Creek, Brisbane, QLD (27°32′S 152°52′E)

OTHER LOCALITIES. Joyner, Pine Rivers, QLD (27°17′S 152°56′E); Ferny Hills, Pine Rivers, QLD (27°23′S 152°56′E)

TYPE MATERIAL. Holotype deposited with the Queensland Museum (Brisbane, Australia), accession number: G463727.

DESCRIPTION. (Fig. 2A–C). Body elongate; rounded anterior rostrum grades into an ovoid mid-body, tapers posteriorly into a long tail; 16-40 (28) µm long by 6.4-13 (9) µm wide; shape index (length to width ratio) 2.3-4.4 (3.1). Anterior rostrum 1.6-6.4 (4) µm long, bears 4 flagella bands which spiral clockwise around the rostrum, approximately 1.5 gyres per band; flagella 8-16 (9.8) µm long, not adherent to the cell, confined to the rostrum giving the cell an

anterior tuft-like appearance. Single nucleus, spherical 1.6-3.2 (2.1) µm diameter, consistently located centrally in the cell at the level of base of the rostrum, 1.6-6.4 (4.2) µm from anterior of cell. Two parabasal bodies, ovoid to spherical flank the nucleus, level with base of the rostrum. Axostyle extends from nucleus to posterior end of cell, slightly curved along its length, non-projecting.

DIFFERENTIAL DIAGNOSIS. Whilst the original description of *M. grassei* Hollande & Carruette-Valentin, 1971 is quite lacking in detail as to what are the diagnostic features of the species, the accompanying photos clearly show that it is a squat species almost oval in outline with a short, narrow posterior tail. In contrast *M. scottae* is elongate, the cell being approximately 3 times as long as it is wide, and has a posterior tail almost as wide as the anterior portion of the cell. Additionally, in *M. grassei* the flagellar bands extend posterior to the nucleus, are connected to parabasal bodies and individual flagella are adherent in the proximal portion. None of these features occur in *M. scottae*.

ETYMOLOGY. *M. scottae* is named in honour of a friend whom I (SLC) failed, Kirsten Scott.

Ultrastructure. (Figs 3A–F). Individual flagella are derived from a central core which runs axially within the cell, each flagellum is angled approximately 12-18° relative to the previous flagellum in the band (Figs 3B, E, F), one full rotation around the cell thus consists of about 20-30 flagella with increasing numbers of flagella in the posteriormost bands (Fig. 3F), each band wraps around the cell about one and a half times and there are 4 independent bands. Each flagellum extends out perpendicularly or nearly so from the central core, thus more posteriorly located flagella are surrounded by more cytoplasm than anterior ones. Each kinetosome does not appear to be anchored to any particular structure, each is close to a centre tubular structure but not connected to it nor intimately associated with the striated lamina. Peltoaxostylar and preaxostylar fibres arise from the anterior most kinetosomes and are directed towards the anterior membrane of the cell (Fig. 3E). The peltoaxostyle is external to the preaxostyle and is much longer. The dense lamina is absent. A striated lamina is derived from the bottom edge of the kinetosomes and extends posteriorly, approximately paralleling the course of the flagellar band towards the nucleus (Figs 3D, E). The striated lamina surrounds the nucleus and gives rise to the axostyle (Fig. 3D). The axostyle proper runs posteriorly from the base of the nucleus and is composed of a rolled sheet of microtubules surrounding a low-density cytoplasm (Fig. 2A). It extends almost to the posterior end of the cell but does not project beyond the cell (Fig. 2A). There are 2 Golgi bodies which flank the nucleus, posterior to the bottom-most flagella; the parabasal fibre which connects the Golgi bodies to the kinetosomes is absent (Fig. 2A). Electron-dense bacteria appear to be scattered randomly within the cell, several are located near the flagellar bands whereas others occur throughout the body (Figs 3C, F). Food-vacuoles are mostly present within the posterior 'tail-like' portion of the cell and do not appear to contain whole wood fibres (Fig. 2A).

REVISED GENERIC DIAGNOSIS. *Micromastigotes* Hollande & Carruette-Valentin, 1971. Polymastigont flagellates with flagella arranged into bands which spiral around an anterior rostrum in a clockwise direction. Flagella bands are derived from the centre of the cell and radiate like a spiral stair-case. A flagellar gutter connecting individual flagella in each band is absent. Axostyle present, derived from the striated lamina which extends from the posterior of each kinetosome. Nucleus and Golgi bodies located immediately posterior to the flagella bands.

DIFFERENTIAL GENERIC DIAGNOSIS. It is difficult at this time to definitely assign *Micromastigotes* to any parabasalid family and we propose to leave it as a Spirotrichonymphina *insertae sedis* pending a better understanding of relationships amongst these groups. *Micromastigotes* is most readily confused with members of the Spirotrichonymphinae Grassi, 1917; namely *Spirotrichonympha*, *Microjoenia* and *Spirotrichonymphella*. *Micromastigotes* is readily distinguished from the first two genera by the absence of the flagellar gutter and the origin of the flagella in the central axis of the cell. *Micromastigotes* is distinguished from *Spirotrichonymphella* by the restriction of the flagella bands to the anterior portion of the cell; in *Spirotrichonymphella* the bands cover the whole cell.

DISCUSSION

TAXONOMIC STATUS

The original description of *Micromastigotes* by Hollande & Carruette-Valentin (1971) provided a basic description of the species and of what set

this genus apart from other parabasalid flagellates. There was no line diagram of the whole cell but the series of photographs of silver-stained cells and several transmission electron micrographs serve to illustrate the most significant features of the genus, i.e. flagella arising from an anterior rostrum and their derivation from a central spiral within the core of the cell. The features of *Micromastigotes* grassei included:

- spiral flagellar bands arising on an anterior rostrum and which do not form an anterior column or converge in the posterior of the cell;
- large dictyosomes which are widely separated;
- individual flagella are proximally adherant;
- nucleus is apical within the cell;
- axostyle resembling a compact rod and projects posteriorly;
- anteriormost region has a clear cytoplasm, without inclusions, fibrils or tubules;
- flagellar bands, under the cap are enclosed by morphoplasm and are interconnected with each other in 2 independent groups. On its origin each band has the same structure as the those in *Spirotrichonympha*. An ergoplasmic cistern (reticulum?) runs along the flagellar bands and it is between them, where the dictyosomes are in place.
- basal bodies have their cavity filled with glycogen and are connected by electron dense material
- the anterior basal bodies give rise to a preaxostyle that induces the microtubules of the pelta and the axostyle
- axostyle fibrilles enclose a cytoplasm that contains glycogen
- dictyosomes are piled up in a dozen very long cisterns. These contain an electron dense mass. Frequently there are multiple successive sacks, which contain a dense material at the same level, 6-8 saccules are present and are associated with each other by a dense substance.

There are, however, differences between *M. grassei* and *M. scottae*. The flagellar bands of *M. grassei* extend posterior to the nucleus whereas in *M. scottae* they are anterior to it; the flagella are adherent in *M. grassei* but non-adherent in *M. scottae*; the flagellar bands of *M. grassei* are accompanied by parabasal bodies whereas there is no connection between the parabasal bodies and flagellar bands of *M. scottae*; there is no striated lamina recorded in *M. grassei* but it is prominent in *M. scottae* and finally the basal bodies of each flagellar band are connected by electron dense material in *M. grassei* whereas this doesn't appear to be the case in *M. scottae*. Of these differences the first two, distribution of the flagellar bands and adherant flagella are known to vary within parabasalid genera (Lingle & Salisbury, 1995; Radek, 1997) and so are not sufficient to justify erection of a new genus for *M. scottae*. The published electron micrographs of *M. grassei* (Hollande & Carruette-Valentin, 1971 henceforth H & C-V, 1971) make it difficult to interpret the form of the parabasal bodies. The longitudinal tEM section of *M. grassei* (Fig. 51, H & C-V, 1971) depicts only the anterior of the cell and does not extend to the level of the parabasal bodies which flank the nucleus in *M. scottae*. The written description of *M. grassei*, however, refers to dictyosomes, the form of which is consistent with the bodies found in *M. scottae*. Additionally, in *M. grassei* there is a long cistern of the endoplasmic reticulum which follows the flagellar band (Fig. 52a, H & C-V, 1971). This feature may have been misinterpreted by Hollande & Carruette-Valentin (1971) as it occupies the same position as the striated lamina in *M. scottae* and the published micrographs include ribbon like structures labeled in one figure parabasal lamina (lames parabasales in the original French) which is simply another term for the striated lamina (Fig. 51, H & C-V, 1971) but labelled endoplasmic reticulum in another (Fig. 52a H & C-V, 1971). The electron dense material which connects the basal bodies of *M. grassei* doesn't seem to be present in *M. scottae* but the density of this material seems to vary considerably between the three published micrographs of *M. grassei* so it is hard to determine the significance of this feature.

The key similarity between *M. grassei* and *M. scottae* is the overall structure of the kinety system – flagella bands which spiral from a central core which is oriented axially within the cell. Furthermore, the absence of any similar arrangement in other hypermastigids makes us confident that these two species belong to the same genus. Most of the characters which we have found to vary between these two species are either known to vary between species in other parabasalid genera (i.e. flagellar band length, adherence of

flagella) or are difficult to interpret on the basis of published electron micrographs alone (parabasal body shape and distribution, striated lamina and electron dense connections between the basal bodies). Additionally, none of these features are consistently used for generic level discrimination within parabasalid flagellates whereas the arrangement of the flagella structures has proven to be very valuable and consistent (e.g. Brugerolle, 2001; Brugerolle & Lee, 2000). Whilst it is probable that a thorough reinvestigation of *M. grassei* may clarify many of these issues, at present we prefer to adopt a conservative taxonomic approach, assigning *M. scottae* to *Micromastigotes* rather than erect yet another monotypic genus whose relationships to other parabasalid flagellates is poorly understood.

A complicating factor is *Spirotrichonympha minor*, Radek, 1997. In his revision of the ultrastructure of the Spirotrichonymphidae, Brugerolle (2001) suggested that *S. minor* may be a member of *Micromastigotes* in which case the characteristics of this species must also be taken into account in revision of the latter genus. The description of *S. minor* by Radek (1997) does not include clear evidence for the presence of a flagellar gutter which may give the impression of similarity to *M. grassei*, particularly if one accepts that the striated lamina is absent in *M. grassei*. We have demonstrated the presence of a striated lamina in *M. scottae* in the present study and it is possible that it is also present in *M. grassei* but has been misinterpreted as being part of the endoplasmic reticulum. Furthermore, *S. minor* lacks the arrangement of the flagellar bands which we have found to be diagnostic of Micromastigotes. With the exception of lacking a flagellar gutter the structure of the flagellar bands in *S. minor* is much more similar to that of other *Spirotrichonympha* spp. in that the band is composed of peripheral basal bodies which are interlinked by electron dense material (Brugerolle, 2001; Radek, 1997). Other shared ultrastructural features include peripheral parabasal bodies (*S. mirabilis*, *S. grandis*, *S. elongata*), adherent flagella (*S. grandis*), and flagella bands which extend to the posterior of the cell (*S. mirabilis*, *S. grandis*, *S. elongata*). Of these features, peripheral, ovoid parabasal bodies distributed along the length the flagellar bands are particularly important. In *M. grassei*, the parabasal bodies associated with the flagellar bands are described (if one does not accept our contention that this structure is probably the striated lamina) as a single, narrow cisternae which parallels the flagellar band (Hollande & Carruette-Valentin, 1971) whereas in each of the *Spirotrichonympha* species examined the parabasal bodies are discrete ovoid structures composed of a stack of multiple cisternae, and several separate parabasal bodies are distributed down the length of the flagellar band. *Spirotrichonympha* is, by parabasalid standards, a large genus with 27 recognised species (Radek, 1997; Yamin, 1979) in two subgenera, so there is clearly scope for variation within this genus. Furthermore, *Spirotrichonympha* has recently been shown to be polyphyletic with respect to the genus *Holomastigotes* (Ohkuma et al, 2005). Detailed ultrastructural studies are lacking for the species for which molecular data is available and vice versa, precluding resolution of this matter at the present time, but it seems at least plausible that *Spirotrichonympha* must consist of at least 2 genera with divergent morphologies – one represented by *S. mirabilis*, *S. grandis* and *S. elongata* which possess the features defined by Brugerolle (2001) and the other represented by *S. minor* and defined by the different combination of features outlined in Radek (1997). Additional studies will help to clarify their relationships, but none of the four *Spirotrichonympha* species which have been examined ultrastructurally are sufficiently similar to *Micromastigotes* to warrant their inclusion in this genus or the inclusion of *M. scottae* in *Spirotrichonympha*.

BIOGEOGRAPHY AND HOST ASSOCIATIONS

The description of a second species of *Micromastigotes* raises an interesting issue about the geographic distribution of this genus. The type species, *M. grassei*, was collected from *Postelectrotermes praecox* on the island of Madeira, off the Atlantic coast of Africa. *Micromastigotes scottae* was found at almost the opposite end of the globe, in *Schedorhinotermes intermedius* in Queensland, Australia. This seemingly widely disparate distribution is easier to understand when the distribution of the respective hosts is taken into account. While both host species have comparatively small distributions in North Africa and adjacent islands and northeastern Australia respectively, the genus *Postelectrotermes* is widely distributed, its 13 species spread over Africa, the Middle East and India, whereas *Schedorhinotermes* broadly overlaps this distribution, its 36 species stretching from Melanesia, to Australia, through the Indonesian archipelago, Asia and into north Africa (Constantino, R. website: http://www.unb.

br/ib/zoo/docente/constant/catal/catnew.html; Myles, T. website: http://www.utoronto.ca/forest/termite/termite.htm). Thus, there is considerable scope for local mixing between one or several species from each genus possibly resulting in host switching. This, combined with the fact that North African and Asian termites have been the least investigated for their flagellate faunas (Yamin, 1979), makes it probable that there are undescribed species of *Micromastigotes* occurring through this intervening area.

Even more interesting than the geographic distribution *Micromastigotes* is the broad taxonomic range of the hosts which it infects; *Postelectrotermes* is a kalotermitid whereas *Schedorhinotermes* is a rhinotermitid. These two families of termites have radically different lifestyles. Kalotermitids construct colonies within sound dry wood (including living trees) whereas rhinotermitids are subterranean, the main colony being constructed in fallen timber and foraging trails radiating out under the ground and up trees within tubular galleries made of cemented soil (Watson & Gay, 1991). These differences in host life-style have been frequently mirrored in differences in the taxa of flagellates which occur within them e.g. devescovinids, calonymphids and oxymonads are confined to kalotermids, and eucomonymphids and holomastigotoidids to rhinotermitids (Brugerolle & Lee, 2000; Dolan et al., 2000a, 2000b; Yamin, 1979). Groups which have wider distributions across multiple termite families include the trichonymphids and spirotrichonymphines (Yamin, 1979) suggesting that *Micromastigotes* may be related to one of these.

SYSTEMATIC PLACEMENT OF MICROMASTIGOTES

Hollande & Carruette-Valentin (1971) noted the possible relationship of *Micromastigotes* to other spiral-form hypermastigids and proposed that they formed a natural group without assigning the new genus to an existing or novel family but rather placing it as a genus *insertae sedis* within the suborder Spirotrichonymphina. They did, however, propose several characters upon which the spirotrichonymphines could be split into families (and presumably could be used to place Micromastigotes) including: presence or absence of a rostral column and flagellar bands; numbers of flagellar bands; whose portion is not differentiated out of the parabasal lamellae; position of the nucleus; contingent permanence of the axostyle in cytokinesis; and possible mode of nutrition. Unfortunately, most of these characteristics appear to be of little value in imposing a familial classification upon the spirotrichonymphines. The rostral column, as seen in light microscopy, is an artefact of the cell shape and thus is plastic even at the species level. The columella, a defined fibrillar structure is not always responsible for the appearance of a rostral column under light microscopy. Flagellar bands are a feature of all genera, but if restricted to denote those species which possess a flagellar gutter, this does split *Micromastigotes* and *Spirotrichonymphella* and some from the remaining genera. This feature is, however, variable within *Spirotrichonympha*; flagellar gutters occur in three species examined by Brugerolle (2001), *S. mirabilis*, *S. grandis* and *S. elongata* but are absent in *S. minor* (Radek, 1997). The numbers of flagellar bands are known to be variable within the genera *Spirotrichonympha* and *Holomastigotoides* (Radek, 1997), and it is thus unlikely to be valuable above the generic level. As emphasised above, the differentiation of the parabasal (= striated) lamina is a useful character in understanding the differences between simpler genera such as *Micromastigotes* and the more complex ones. The position of the nucleus is of limited variability within the group and is generally located at the base of the flagellar bands or at the point where the cell expands in diameter. In both cases it is close to the flagellar bases so the fibrous support structures can reach it. The presence of the axostyle throughout cell division has been emphasised as a significant character by Cleveland et al. (1934). It is, however, difficult to apply generally as complete cell cycles are known for only a handful of genera and we currently have no idea how variable this character is within genera. The only characters which show consistent and interpretable variation across the spirotrichonymphines are those related to the mastigont system and its support fibres.

Flagella structure in the spirotrichonymphids was reviewed by Brugerolle (2001) who homologised the anterior end of the spirotrichonymphid flagella band with the privileged flagella. Each band has a complete set of privileged flagella at its anterior end and the majority of the band is composed of the linearly replicated flagellum 3. In addition, each genus within the family could be diagnosed on the basis of modifications of the flagellar gutter – the complex of striated and dense lamella which formed a U-shaped band at the base of the kinetosomes. Brugerolle (2001), however, noted that *Spirotrichonymphella* lacked

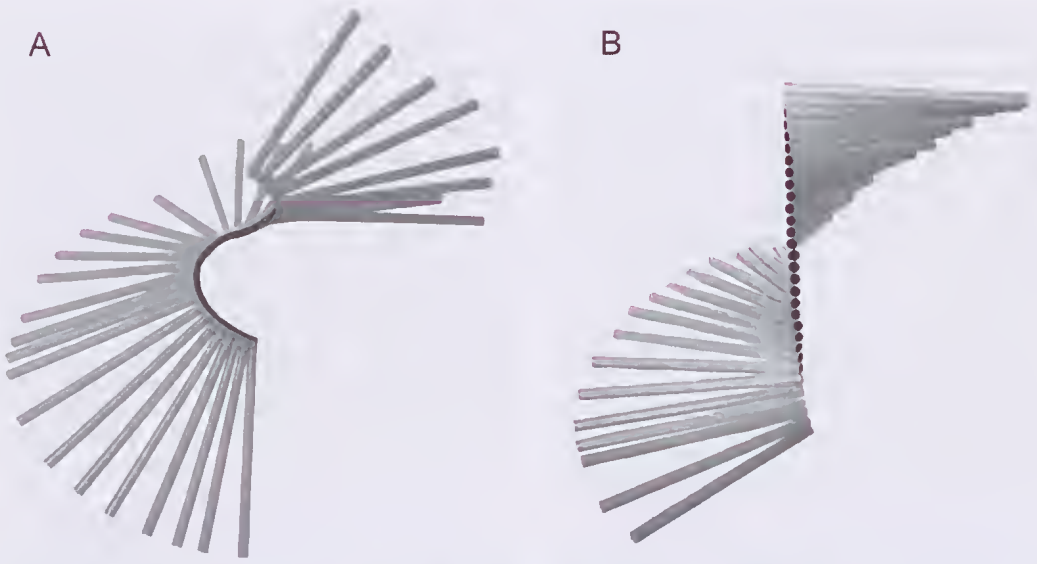

FIG. 4. Schematic diagram of flagellar band structure in the Spirotrichonymphina; each represents a single band for simplicity, all extant species have multiple bands arranged with radial symmetry. A, Spiralised linear band of nearly parallel basal bodies as found in *Spirotrichonympha, Microjoenia, Holomastigotoides*. B, Spiral stair case, basal bodies each rotated several degrees relative to the preceding body as found in *Micromastigotes*.

a flagellar gutter, the kinetosomes were connected to a central core-like structure, the columella, by striated roots and the striated lamella formed a weak band at the base of the kinetosome. This is a broadly similar arrangement to that seen in *Micromastigotes*, however the striated roots are absent. In both cases, the kinetosomes radiate from a central core, the kinetosome bases are buried deep in the cytoplasm, the dense lamina is absent and the striated lamina forms a sheet rather than a curved half of the U-shaped flagellar gutter. Conversely, *Spirotrichonymphella* lacks an axostyle, flagellar bands extend the entire length of the cell and the basal bodies are not anchored directly together in the axial centre of the cell but rather are anchored to the columella by striated roots. This suggests that *Micromastigotes* should probably be classified within the spirotrichonymphines and that the similarities to *Spirotrichonymphella* are probably not indicative of a close relationship between the two genera.

Brugerolle's (2001) homologisation of the anterior ends of the flagella bands of spirotrichonymphines with the privileged flagella of trichomonads *sensu lato* provides further evidence of the distinction between *Micromastigotes* and the other Spirotrichonymphidae. The arrangement of the flagella bands in most spirotrichonymphines suggests that the privileged flagella are oriented perpendicularly to the cell membrane, the mutliflagellate condition is achieved by serial replication of flagellum 3 and spiralisation is then achieved by torsion of the band (kinetosomes plus flagellar gutter) around the cell, individual flagella are roughly parallel to each other at their bases (Fig. 4A). Spiralisation in *Micromastigotes* has clearly not been achieved in this fashion. Flagella are oriented perpendicularly to the axis of the cell and spiralisation is achieved by rotation of kinetosomes around this central axis, by about 12-18° per flagellum in *M. scottae* (Fig. 4B). The distinction here is not simply related to size. Whilst most spirotrichonymphids are quite large species for which peripheral flagellar bands are the only functional option (flagella radiating from a central core may embed too much of the flagellum shaft in cytoplasm for them to beat effectively) the peripheral location of the flagellar bands occurs in even the smallest spirotrichonymphids. *Microjoenia anterodepressa* is only two thirds the size of *Micromastigates scottae* and yet displays the classical spirotrichonymphid arrangement of peripheral flagella bands bounded internally by a flagellar gutter (Brugerolle, 2001). The evolutionary relationships of the spirotrichonymphid genera are currently unknown, so it is impossible to discern whether *Microjoenia*

is a small, plesiomorphie genus whieh already demonstrates the eharaeteristies whieh were retained in larger genera, or it is a derived genus whieh has undergone reduetive size evolution but still retains features of larger aneestors.

Thus, if *Micromastigotes* is not a spirotriehonymphine, it most likely represents another independent adoption of the hypermastigont eondition. This may have oeeurred by serial replieation of the reeurrent flagellum. In most triehomonads, the reeurrent flagellum is oriented perpendicularly to the long axis of the eell and to the other flagella (Brugerolle, 1999; Cleveland, 1961; Honigberg et al., 1968; Mattern et al., 1967). The reeurrent flagellum is thus already in the eorreet orientation and its formation at an angle to the other flagella may have predisposed it to start a spiralisation proeess whose end produet we see in *Micromastigotes*. Set against this idea is the faet that the reeurrent flagellum is frequently modified in triehomonad groups, with the addition of a eresta in deveseovinids or as part of the undulating membrane in many triehomonadids, whereas the flagella of *Micromastigotes* are not expanded or modified in any way. For this evolutionary seenario to be tenable, *Micromastigotes* would have to be related to a group with an unmodified reeurrent flagellum. Given the diffieulties of subjectively resolving ultrastruetural homologies, the best solution is probably to generate moleeular phylogenies for the groups of interest. Whilst sometimes initially at odds with traditional morphologieal based elassifieations, re-evaluation of morphological struetures in light of well-resolved, independent phylogenies has proven to be a very useful eourse of aetion (e.g. Brugerolle & Patterson, 2001 for the Cristamonadida). Only then can we really address the questions raised by *Micromastigotes*: is it most elosely related to the spirotriehonymphines or some other parabasalid group, is its similarity to *Spirotrichonymphella* more than eoineidental, does the odd flagella strueture of *Micromastigotes* really represent another adoption of the polymastigont eondition, and what do parabasalids need with so many extra flagella for it to have evolved independently on so many oeeasions?

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A NEW SPECIES OF *PHYLLURUS* (LACERTILIA: GEKKONIDAE) FROM THE KILKIVAN DISTRICT OF SOUTH-EASTERN QUEENSLAND.

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Couper, P.J., Hamley, B. & Hoskin, C.J. 2008 04 30: A new species of *Phyllurus* (Lacertilia: Gekkonidae) from the Kilkivan district of south-eastern Queensland. *Memoirs of the Queensland Museum* **52**(2): 139-147. Brisbane. ISSN 0079-8835.

The leaf-tailed geeko *Phyllurus kabikabi* sp. nov. is described from Oakview Forest Reserve in the Kilkivan district of south-eastern Queensland. It has a very restricted distribution and is deeply divergent from its sister taxon, *P. caudiannulatus*, from which it is readily separated in morphology by lacking enlarged tubercules on the underside of the hindlimb. The Oakview Forest Reserve/State Forest area is of conservation significance, harbouring relict rainforest taxa, including the largest known population of the rare skink, *Nangura spinosa*. Potential threats to *P. kabikabi* sp. nov. include a narrow distribution and degradation of habitat through logging, feral pigs and fungal pathogens. ❐ *Gekkonidae, Phyllurus, new species, Queensland, Australia, rainforests.*

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In late February 1997, a leaf-tailed geeko (*Phyllurus* sp.) was captured (by BH) in what was then Oakview State Forest (26° 07' 23"S 152° 19' 01"E) during vertebrate fauna surveys that were part of the Queensland/Commonwealth Government funded South East Queensland Bioregion Comprehensive Regional Assessment (Eyre et al., 1998). The collection site is currently in Oakview Forest Reserve, a protected area estate managed by the Queensland Environmental Protection Agency. The specimen was a small juvenile without a tail which made it difficult to assess its morphologieal affinities with other *Phyllurus* spp. In September 1997, the collection site was revisited by a team from the Queensland Museum and the Department of Natural Resources in order to colleet additional material. A further six speeimens were obtained, some with original tails. The geckos closely resembled specimens of *P. caudiannulatus* Covacevich from Bulburin National Park/State Forest area (24°37'05"S 151°32'37"E), 195km to the north. Geckos from both populations shared a divided rostral scale and had cylindrical tails with bold white cross bands.

Genetic analysis showed the Oakview *Phyllurus* population to be a highly divergent sister lineage to *P. caudiannulatus* (Couper et al., 2000; Hoskin et al., 2003). Couper et al. (2000) discussed the status of the Oakview leaf-tails, treating them tentatively as a divergent population of *P. caudiannulatus*, pending examination of more material and surveys of suitable habitat in areas between the Bulburin and Oakview populations. We believe the intervening area has now been well surveyed and no additional *Phyllurus* populations have been found. An assessment of the Oakview *Phyllurus* eollection site determined that the total known area of occupancy may be as little as 6.1ha (Borsboom, 2006) and therefore no additional specimens were colleeted. Based on the high genetic divergence and geographic separation between *P. caudiannulatus* and the Oakview *Phyllurus* population, as well as consistent morphological differences presented herein, we here describe the Oakview *Phyllurus* as a new species.

MATERIALS AND METHODS

MORPHOMETRICS. All measurements were taken with Mitutoyo electronic eallipers. The single juvenile specimen is exeluded from measurements given as percentage SVL.

DEFINITIONS. Snout to vent length (SVL), tip of snout to anterior margin of cloaca with body straightened; tail length (T), from posterior margin of cloaca to tip of tail; head length (HL), mid anterior margin of ear to tip of snout; head width (HW), widest point across baek of skull, corresponding with anterior upper margin of ear openings; head depth (HD), lower jaw to top of head, between eyes; snout length (S), anterior margin of orbit to tip of snout; eye to ear (EE), posterior margin of orbit to mid anterior margin of ear; neck length (NL), axilla to mid posterior margin of ear; length of forelimb (L1), insertion to tip of longest digit, with limb stretched straight

perpendicular to body; length of hindlimb (L2), insertion to tip of longest digit, with limb stretched straight perpendicular to body; axilla to groin (AG); subdigital lamellae (fourth finger, fourth toe), tip of digit to basal junction of third and fourth digits; supralabial and infralabial scale rows (from rostral and mental scales, terminating posteriorly at the angle of the mouth when the labials cease to be twice the size of adjacent granules). The distribution of enlarged tubercules was examined on the hands, feet and ventral surfaces.

SURVEYS. The Environmental Protection Agency (2007) WildNet Database was searched to determine the survey effort at localities in close proximity to Bulburin National Park (24°37'05"S 151°32'37"E) and Oakview Forest Reserve (26° 07' 23"S 152° 19' 01"E) and at latitudes between these two sites (see Appendix). The data search drew on records from multiple sources (Integrated Biological Information System, Moggill Queensland Parks and Wildlife Service Fauna Data, SEQ Comprehensive Regional Assessment Fauna Survey Database and Wildlife Ecology - Indooroopilly survey data). Additional sites were assessed by Queensland Museum herpetologists in November 1999.

SYSTEMATICS

Phyllurus kabikabi sp. nov.
(Figs 1A, 2A, 3)

ETYMOLOGY. Derived from Kabi Kabi (pronounced car-bee car-bee) to recognise the language group of the traditional owners of Oakview Forest Reserve. The name Kabi is derived from the traditional name Kav'ai or Kab'ai being the name for the native light grey bee and pronounced car-by.

MATERIAL. HOLOTYPE: QMJ63857 Oakview Forest Reserve (26° 07' 23"S 152° 19' 01"E), 25 Sept 1997. PARATYPES: QMJ62817, QMJ63849-63853. Details as for holotype except QMJ62817 was collected 26 Feb 1997.

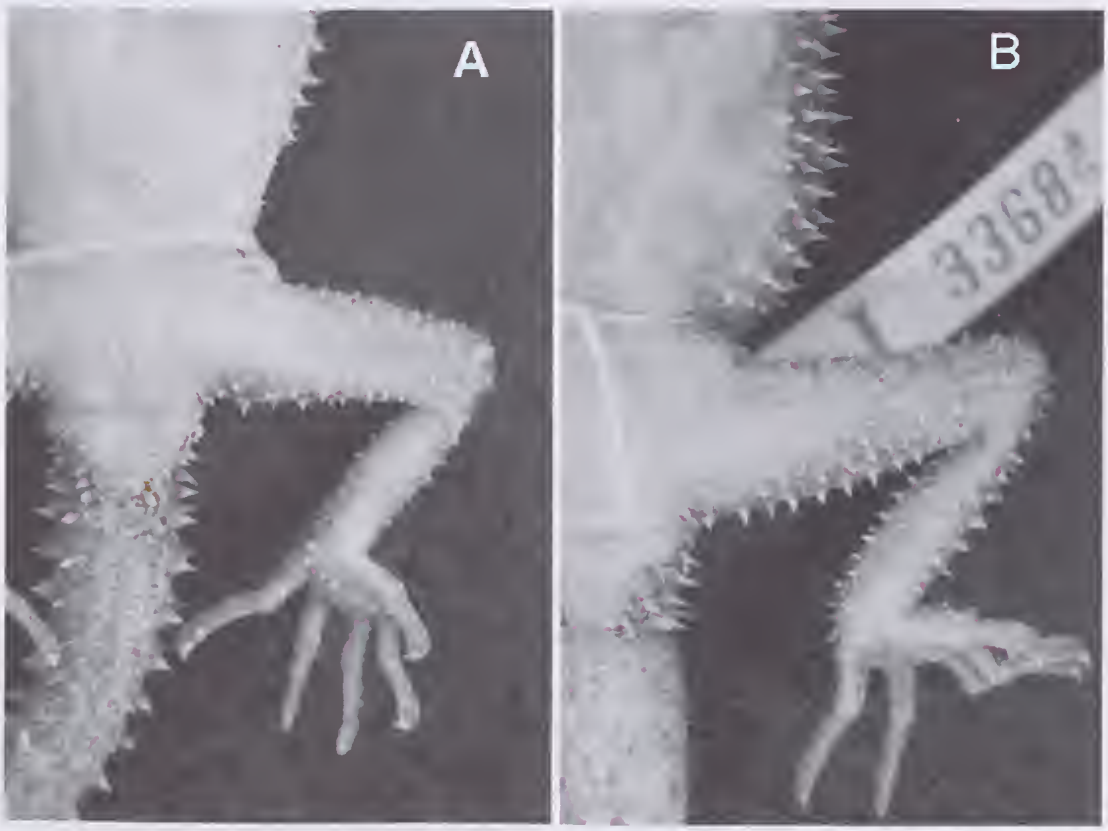

FIG. 1. Scalation on ventral surface of the hindlimb. A, *Phyllurus kabikabi* sp. nov. (QMJ63857) - enlarged tubercules absent; B, *P. caudiannulatus* (QMJ63684) - enlarged tubercules present. Also note the more spinose flanks of *P. caudiannulatus*.

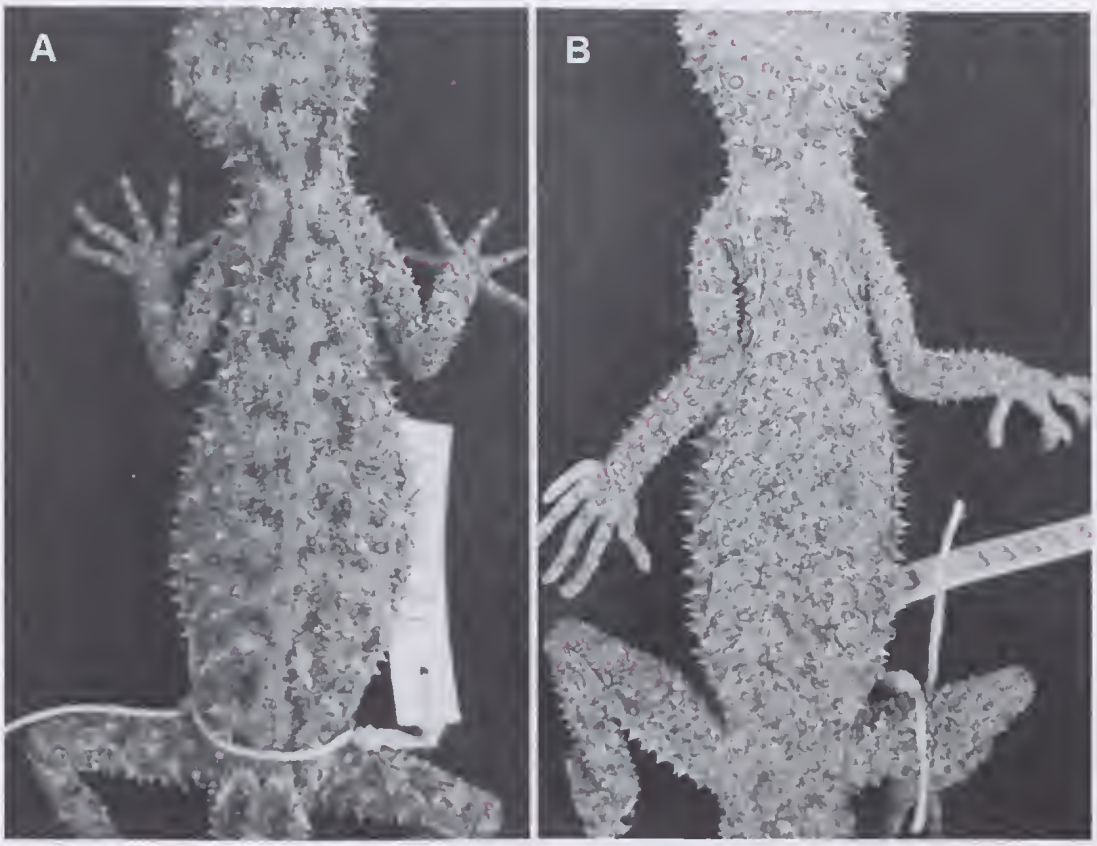

FIG. 2. Dorsal scalation of A, *Phyllurus kabikabi* sp. nov. (QMJ63857) and B, *P. caudiannulatus* (QMJ33693) showing the latter species to be generally more spinose along the vertebral line and neck.

DIAGNOSIS. *Phyllurus kabikabi* sp. nov. is separated from all its congeners by the following combined characters: tail cylindrical; rostral scale fully divided; ventral surface of hindlimb lacking pronounced, raised tubercules (Fig 1A).

DESCRIPTION. SVL (mm): 52.01 - 81.10 (n = 7, mean = 68.72, SD = 9.75). Proportions as % SVL: T = 70.12 - 77.83 (n = 3, mean = 75.14, SD = 4.35); HL = 24.93 - 28.65 (n = 6, mean = 27.20, SD = 1.35); HW = 21.15 - 23.10 (n = 6, mean = 22.64, SD = 0.74); S = 11.39 - 13.08 (n = 6, mean = 12.10, SD = 0.59); EE = 8.03 - 9.52 (n = 6, mean = 8.90, SD = 0.52); NL = 18.13 - 21.47 (n = 6, mean = 19.60, SD = 1.29); AG = 41.35 - 46.87 (n = 6, mean = 44.05, SD = 2.01); L1 = 40.65 - 44.89 (n = 6, mean = 43.13, SD = 1.56); L2 = 48.14 - 54.83 (n = 6, mean = 52.82, SD = 2.45).

Head. Large, depressed, triangular, distinct from neck; head depth 38.70 - 42.27% head width (n = 7, mean = 40.34, SD = 1.12); covered in small granules intermixed with larger conical tubercles; skin of head co-ossified with skull; rostral shield fully divided by deep, vertical groove (n = 7); rostral shield not in contact with nostril (n = 7); scales between nasal openings along dorsal edge of rostral 7 - 9 (n = 7, mode = 9, mean = 8.14, SD = 0.90); ear opening elliptical, vertical, much less than half as large as eye; supralabials (left) 14 - 18 (n = 7, mode = 16, mean = 16, SD = 1.30), supralabials (right) 13 - 18 (n = 7, mode = 16, mean = 15.29, SD = 1.70); infralabials (left) 12 - 16 (n = 7, mode = 13, mean = 13.29, SD = 1.38), infralabials (right) 12 - 16 (n = 7, mode = 13, mean = 13.57, SD = 1.51). ***Neck.*** Broad. *Body.* Moderate, depressed, covered in small granules; dorsal granules intermixed with larger conical tubercles; tubercles small to moderate on back and flanks, moderate to pronounced on sides of neck; basal scales surrounding upper flank and back tubercules not, or slightly, larger than adjacent granules; ventral scales slightly enlarged in pelvic region; small

granules present on pectoral region. Preanal pores absent. Axilla deeply invaginated. *Limbs.* Long, covered in small to moderate pointed tubercles dorsally; enlarged tubercules on ventral surface of upper forelimb; underside of hindlimbs without enlarged tubercules (Fig. 2A); digits strongly compressed distally; subdigital lamellae fourth finger (left) 16 - 20 (n = 7, mode = 18, mean = 18.14, SD = 1.35), fourth finger (right) 16 - 19 (n = 7, mode = 16, mean = 17.0, SD = 1.15); dorsal surface of hand without enlarged conical tubercules; subdigital lamellae fourth toe (left) 14 - 18 (n = 7, mode = 16, mean = 16, SD = 1.29), subdigital lamellae fourth toe (right) 13 - 18 (n = 7, mode = 16, mean = 15.29, SD = 1.70); dorsal surface of foot with some enlarged conical tubercules. *Original tail.* Cylindrical, tapering and terminating in small knob. Dorsal surface with transverse rows of enlarged, spinose tubercules, 10 proximally, 8 on mid region, free of enlarged spinose tubercules for 8 - 16% of distal tail length; ventral surface with small granular scales. *Regenerated tail.* Cylindrical with granular scalation, lacking enlarged spinose tubercules; tip slightly bulbous.

Pattern. In spirit, head body and limbs fawn to mid-brown; heavily marked with irregular dark brown blotches on head body and limbs. Two pairs of small, indistinct cream blotches on either side of vertebral line; one over pectoral region, other over pelvic region (most prominent in juvenile QMJ62817 and holotype QMJ63857), but only just discernible in remaining specimens). Head with a short, cream streak running from posterior edge of orbit to angle of mouth. Toes with obscure cream cross bands. Original tail as for body, but more heavily mottled and generally of darker appearance; with 5 distinct cream cross bands (? 6 in QMJ63849) of which distal 3 extend to ventral surface. Ventral surfaces cream with faint brown 'peppering' on edges of chin and belly, and limbs; conspicuous dark 'peppering' beneath original tail. Regenerated tail heavily pigmented all over (QMJ63853, with partially regenerated tail, has a distinct 'V' shaped marking on dorsal surface).

Measurements and scale counts of holotype. QMJ63857 SVL = 81.1 mm, T (original) = 56.87 mm, HL = 20.22 mm, HW = 17.15 mm, HD = 6.87 mm, S = 9.24 mm, EE = 6.51 mm, NL = 14.7 mm, L1 = 32.97 mm, L2 = 39.04 mm, AG = 38.01 mm, Lamellae 4th finger (17 left, 16 right), Lamellae 4th toe (16 left, 16 right), supralabials (16 left, 16 right), infralabials (13 left, 12 right).

Genetics. The phylogenies presented in Couper et al. (2000) and Hoskin et al., (2003) clearly identify *P. kabikabi sp. nov.* (referred to as *P.* cf. *caudiannulatus* Oakview and *P. caudiannulatus* Oakview SF SEQ respectively) as the sister taxon to *P. caudiannulatus* from Bulburin National Park/ State Forest area. Sequence divergence between *P. kabikabi sp. nov.* and *P. caudiannulatus* is 14.52% (399 bp cytochrome *b* mtDNA), a level of divergence comparable to that seen amongst *Phyllurus* spp. in mid-eastern Queensland (12.30% - 17.87%: *P. championae* Schneider, Couper, Hoskin & Covacevich; *P. isis* Couper, Covacevich & Moritz; *P. nepthys* Couper, Covacevich & Moritz and *P. ossa* Couper, Covacevich & Moritz). Couper et al. (2000) estimated the divergence between mtDNA lineages of leaf-tailed geckos to accrue at the rate of 0.0042 ± 0.0002 per million years and suggested the time of divergence between the Oakview population (*P. kabikabi* sp. nov.) and *P. caudiannulatus* to be in the order of 30 million years. This date is comparable with the deep divergence detected in other Australian diplodactyline taxa (*Diplodactylus vittatus* complex; Oliver et al., 2007). As cytochrome *b* is likely to be saturated at deeper divergences, this estimate should be treated tentatively, but nonetheless gives some insight into the antiquity of the split between these taxa.

COMPARISON WITH SIMILAR SPECIES. *Phyllurus kabikabi* sp. nov. can only be confused with *P. gulbaru* Hoskin, Couper & Schneider and *P. caudiannulatus*, its congeners with cylindrical, non-depressed, tapering original and regenerated tails. It is readily separated from *P. gulbaru* by the condition of the rostral scale (rostral fully divided by rostral groove *vs* partially divided in *P. gulbaru*) and the number of pale bands on the original tail (5-6 *vs* 8 in *P. gulbaru*). *P kabikabi* sp. nov. is most similar to *P. caudiannulatus*, which is generally more spinose (Figs. 1-2). It is readily separated by the scalation along the ventral surface of the hindlimb (uniform granules vs granules intermixed with pronounced, raised tubercules in *P. caudiannulatus*, Fig. 1B).

HABITAT. *Phyllurus kabikabi* sp. nov. occurs in a moist semi-evergreen vine forest (Fig. 5) growing on a deep layer of broken, silicic ash-flow tuffs (A. Ewart pers. comm.) capping a ridge summit at an elevation of 540m (Borsboom, 2006). All specimens have been found at night on rock or on vegetation above rock.

FIG. 3. *Phyllurus kabikabi* sp. nov. in life, QMJ63852 (image – G. Cranitch, QM).

DISTRIBUTION. *Phyllurus kabikabi* sp. nov. is known from a single locality in Oakview Forest Reserve (26° 07' 23"S 152° 19' 01"E) SEQ (Fig. 4). A field inspection of the only collection site shows the habitat to be a narrow strip (around 120m at its widest point) covering approximately 6.1ha (Borsboom, 2006). Within Oakview Forest Reserve, there are other upland areas (totalling approximately 1000ha) with similar vegetation that have not yet been assessed for the presence of *P. kabikabi*. sp. nov. However, the distribution of layered rock in Oakview State Forest is patchy and areas without the appropriate substrate are unlikely to support leaf-tailed gecko populations. The strong association between rock and *Phyllurus* spp. is clearly demonstrated in the Sydney sandstones (*P. platurus*) and at many rainforest sites in the Mackay/Townsville regions (*P. championae, P. isis, P. nepthys, P. ossa, P. amnicola* and *P. gulbaru*; Couper et al, 1993, Couper et al. 2000, Hoskin et al., 2003), and it is highly likely to be an important component of the habitat for *P. kabikabi* sp. nov..

The EPA (2007) WildNet database showed considerable survey effort in areas lying between Bulburin State Forest and Oakview Forest Reserve between January 1992 and July 1998. A significant portion of these surveys were conducted by government survey teams using repeatable survey methodologies (see Eyre et al., 1998). No additional *Phyllurus* populations were found. Of twenty five sites surveyed (including national parks, state forests, forest reserves and conservation parks), twelve sites were scored as rainforest and six of these included a nocturnal component in the search effort. Geekos (but not *Phyllurus* spp.) were recorded from all six sites, indicating appropriate techniques and an appropriate search image for detecting their

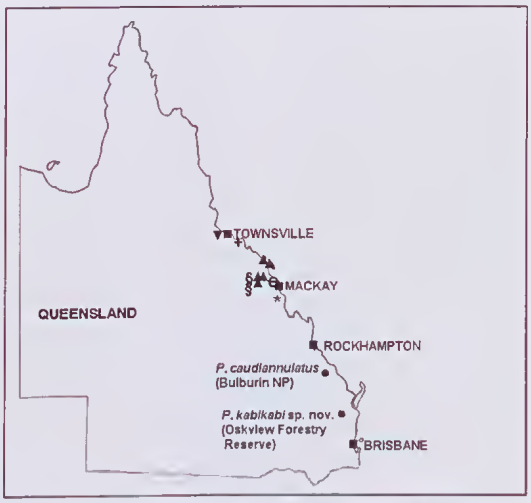

FIG. 4. Map showing the distribution of *Phyllurus kabikabi* sp. nov. (Oakview Forestry Reserve) and *P. caudiannulatus* (Bulburin NP) in relation to other *Phyllurus* spp. in Queensland. ▼ = *P. gulbaru*, + = *P. amnicola*, ▲ = *P. ossa*, Θ = *P. isis*, § = *P. nepthys*, * = *P. championae*.

FIG. 5. Habitat of *Phyllurus kabikabi* sp. nov. at Oakview Forest Reserve. A, semi-evergreen vine forest overlying the leaf-tail site; B, rock substrate at the leaf-tail site.

presence. Geckos (but not *Phyllurus*) were also found at three additional rainforest sites where nocturnal searches were not conducted (presumably found sheltering during the day). In addition to the WildNet data, three sites were searched, by QM herpetologists in November 1999.

Reproduction. The holotype, QMJ63857 which was collected in late September has two oviducal eggs visible through the body wall. The timing of egg-laying is consistent with that observed for *Phyllurus* spp. on the Mackay Coast, MEQ (Couper et al., 1993).

FIG. 6. Habitat disturbance associated with forestry activities in Oakview State Forest. Note the semi-evergreen vine forest abutting the forestry road on right.

Conservation. Phyllurus kabikabi sp. nov. appears to be one of Queensland's most narrowly distributed reptile species. In addition to threats associated with a narrow extent of occurrence, *P. kabikabi* sp. nov. may be at risk from habitat degradation from forest die-back caused by the fungus *Phytophthora cinnamomi*. *Phytophthora cinnamomi* has been shown to have caused localised die-back in rainforests further north in Queensland, on the Eungella Tableland and in the Wet Tropics (Brown, 1999). It has been suggested that *P. cinnamomi* may have been introduced into some of these areas on forestry machinery (Brown, 1999), and that logging activities and feral pigs may increase the spread of the fungus within these areas (Brown, 1999; Gadek, 1999). Given the presence of ongoing logging operations in the adjacent Oakview State Forest (Fig. 6) and the presence of feral pigs in Oakview State Forest and Oakview Forest Reserve (Borsboom pers. comm.), we consider *P. cinnamomi* to be a potential threat to the rainforest at the *P. kabikabi* sp. nov. site. Significant degradation of the vine thicket at the leaf-tail site through disease or other agents (e.g. fire) would have profound consequences for the geckos, affecting moisture levels, prey abundance and other factors. *Phyllurus* species in Queensland are strongly tied to rocky habitats, but only occur where these are associated with rainforest communities. Borsboom (2006) suggested that pigs, cats, foxes and cane toads may impact *P. kabikabi* sp. nov. directly through predation, and cane toads also through food competition. Such impacts have not been assessed, but the authors consider them unlikely to be substantial given that the rugged, rocky terrain that underlies the gecko site limits access to these species.

The Oakview Forest Reserve/State Forest area has attracted considerable attention since the discovery of a significant population of *Nangura spinosa* Covacevich, Couper & James there in 1997. This distinctive, highly localised skink was previously known from a single creek line in Nangur National Park, 38km to the west. Oakview is of importance to the survival of this species, comprising 80% of its known area of occupancy (Borsboom et al., 2005). Additionally, there are concerns as to the small size of the Nangur National Park population of this skink and its long term viability (Borsboom pers. comm.). The discovery of *P. kabikabi*, and its high genetic divergence from *Phyllurus* further north, further highlights the significance of Oakview Forest Reserve and hints at the importance of this landscape as a refugium for rainforest taxa during past climate change. Preliminary investigations also show its importance to other faunal groups. It is home to an undescribed, narrowly distributed weta (family Anostostomatidae) that has only been collected from one other, geographically proximate rainforest site (G. Monteith, pers. comm.).

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APPENDIX

Sites encompassing Bulburin and Oakview State Forests and the intervening areas for which reptile records exist in the Environmental Protection Agency (2007) WildNet (Database). * = Surveyed rainforest site, 2 = nocturnal component to survey, 3 = site visited by QM herpetologists.

Eurimbula NP, 24°07'22"S 151°42'35"E*[2]; Dan Dan NP, 24°09'42"S 151°04'50"E*; Eurimbula Conservation Park, 24°11'50"S 151°42'45"E; Deepwater NP, 24°17'57"S 151°55'45"E; Kroombit Tops NP, 24°22'22"S*[2] 150°57'23"E; Mount Colosseum NP, 24°25'06"S 151°35'30"E; Broadwater Conservation Park, 24°25'55"S 152°00'16"E; Dawes NP 24°30'23"S*[2] 151°13'42"E; Bulburin NP, 24°32'22"S 151°29'12"E*[2]; Dawes Resources Reserve, 24°33'32"S 151°14'48"E; Glassford State Forest, 24°33'36"S 151°20'08"E; Littabella NP, 24°36'24"S 152°3'42"E; Bulburin State Forest, 24°37'05"S 151°32'37"E*[2]; Pine Mountain State Forest, 24°38'20"S 151°12'15"E; Watalgan State Forest, 24°39'14"S152°01'8"E; Warro NP, 24°39'15"S 151°42'23"E; Littabella Forest Reserve, 24°39'33"S 151°58'41"E*[2]; Kalpowar State Forest, 24°40'37"S 151°20'33"E; Mouth of Kolan River Conservation Park, 24°40'42"S 152°12'42"E*; Mon Repos Conservation Park, 24°47'47"S 152°26'31"E; Bullyard Conservation Park, 24°58'35"S 152°03'06"E; Bania Forest Reserve, 24°58'40"S 151°30'20"E*[2]; Wonbah State Forest, 2 24°59'34"S 151°39'01"E; Bingera NP, 25°02'23"S 152°16'39"E; Elliott River State Forest, 25°03'24"S 152°15'31"E; Baywulla Creek Conservation Park, 25°04'03"S 151°25'41"E; Cordalba Forest Reserve, 25°06'43"S 152°05'22"E*[2]; Burrum Coast NP, 25°07'01"S 152°32'55"E; Cordalba State Forest, 25°07'25"S 152°07'15"E; Mt Perry, 25°13'S 151°42'E[3]; Nour Nour Forest Reserve, 25°15'03"S 151°26'42"E; Good Night Scrub NP, 25°16'56"S 151°54'11"E*[2]; Wongi State Forest, 25°27'03"S 152°25'34"E;Woowoonga NP, 25°28'34"S 152°07'0"E; Wongi NP, 25°29'47"S 152°19'35"E*; Degilbo Timber Reserve, 2 25°31'44"S 151°54'27"E*; Wooroo NP, 25°38'18"S 152°19'47"E; Mt Walsh, 25°33'38"S 152°03'20"E[3]; Mount Walsh NP, 25°38'20"S 152°02'30"E*[2,3]; St Mary State Forest, 25°40'57"S 152°27'34"E; Glenbar State Forest, 1 25°45'52"S 152°22'25"E; Mt Bauple, 25°48'30"S 152°34'00"E[3]; Ban Ban NP, 25°50'46"S 151°57'28"E; Teebar Forest Reserve, 1 25°51'10"S 152°04'23"E*; Grongah Forest Reserve, 25°55'45"S 152°7'54"E*[2]; Marodian Forest Reserve, 25°56'38"S 152°13'07"E; Woroon State Forest, 26°03'26"S 151°39'01"E; Nangur NP, 26°07'08"S 151°59'02"E*; Brooyar State Forest, 26°08'36"S 152°30'43"E; Oakview State Forest, 26°09'23"S 152°19'12"E*; Oakview Forest Reserve, 26°09'54"S 152°18'30"E*[2];

Glastonbury State Forest, 26°14'51"S 152°28'57"E*; Wrattens Forest Reserve, 26°17'58"S 152°20'28"E*[2]; McEuen State Forest, 26°20'8"S 151°52'23"E; Wrattens State Forest, 26°21'42"S 152°21'24"E;Wondai State Forest, 26°21'50"S 151°57'31"E; Kandanga Forest Reserve, 26°24'45"S 152°25'08"E; Gallangowan State Forest, 26°26'08"S 152°20'23"E*; Upper Kandanga State Forest, 26°26'24"S 152°23'24"E.

NOTES ON THE DIET OF THE NORTHERN MASKED OWL *TYTO NOVAEHOLLANDIAE KIMBERLI* IN NORTH QUEENSLAND. *Memoirs of the Queensland Museum 52(2): 148.* 2008:– *Tyto novaehollandiae kimberli* is listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth) and *Nature Conservation Act 1992* (Queensland), and as near threatened by Garnett & Crowley (2000). The subspecies *T.n. kimberli* exists at low density throughout its northern Australian range and is reported to be in decline in parts of the Wet Tropics area (Young & De Lai, 1997; Nielsen, 2001).

Little has been published on the diet of *T.n. kimberli* (Higgins, 1999), although they are known to take rats in north Queensland (Hollands, 1991; Nielsen, 1993; Young & De Lai, 1997). Due to this paucity of information Garnett & Crowley (2000) recommended that the dietary composition and conservation status of principal prey be recorded where northern Masked Owls are located.

The diet of Masked Owl subspecies in southeastern Australia and Tasmania is better known and consists mainly of ground-dwelling rodents and small marsupials (Debus, 1993; Mooney, 1993; Peake et al., 1993; Debus & Rose, 1994; Kavanagh, 1996, 2002; Higgins, 1999; McNabb et al., 2003; Todd, 2006).

STUDY AREA AND METHODS. Five fresh pellets were collected from the foot of a tree below a known Masked Owl roosting/nesting hollow at Geraghty Park, Julatten (16° 34' S, 145° 21' E), north Queensland, in September 2006. A Masked Owl was observed leaving the hollow at dusk on 5 and 6 September. Three pellets were collected on 5 September, and while searches on 6 and 7 September failed to locate any more pellets, two further pellets were collected on 12 September. No other owl species were observed in Geraghty Park on 5-6 September (pers. obs.) or for the remainder of the month (K. & L. Fisher, pers comm. 2007). The hollow was located ~20m high in a large Forest Red Gum *Eucalyptus tereticornis* which, along with other nearby scattered trees, represent the last remnants of a eucalypt forest which once existed in the region. Masked Owls have used this hollow for approximately one year (K. & L. Fisher, pers comm. 2007). The surrounding area is a mosaic of mainly cleared pastures used for cattle grazing, sugar cane and rainforest remnants.

Pellets were analysed by ABR, and the minimum numbers of individual prey items determined, by counting skeletal parts and comparison with reference material (i.e. Knox, 1976; Watts & Aslin, 1981).

RESULTS AND DISCUSSION. The three pellets collected on 5 September measured 40 × 31, 40 × 25 and 39 × 34mm and contained, collectively, the remains of three Canefield Rats, *Rattus sordidus*. The two pellets collected on 12 September measured 35 × 28 and 36 × 27mm and contained, collectively, the remains of two Grassland Melomys, *Melomys burtoni*. The size of the pellets is considerably smaller than those recorded for the Tasmanian Masked Owl *T. n. castanops* (see Higgins, 1999).

Both the Canefield Rat and Grassland Melomys have been favoured by the establishment of sugar cane in north Queensland and are considered pests of that industry. Both rodents are among the most numerous small mammals in the Julatten-Mount Molloy district (Burnett, 2001).

The dietary sample from this study is broadly consistent with studies elsewhere in Australia, and particularly those in NSW, where the nominate Masked Owl subspecies *T. n. novaehollandiae* is opportunistic in prey selection, taking locally abundant mammals (Debus & Rose, 1994; Kavanagh, 2002; Todd, 2006).

The decline of the northern Masked Owl has been linked to the use of the now-banned rodenticide *Klerat* to control rats in sugar cane (Young & De Lai, 1997; Nielsen, 2001), although a general decline of mammals in northern Australia has also been suggested as a possible cause (Garnett & Crowley, 2000; Woinarski, 2004). Further quantitative studies on the diet of the northern Masked Owl would assist in identifying potentially threatening processes.

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A NEW GENUS OF GRASS CICADAS (HEMIPTERA: CICADOIDEA: CICADIDAE) FROM QUEENSLAND, WITH DESCRIPTIONS OF THEIR SONGS

A. EWART AND DIANA MARQUES

Ewart, A. & Marques, D. 2008 04 30: A new genus of grass cicadas (Hemiptera: Cicadoidea: Cicadidae) from Queensland, with descriptions of their songs. *Memoirs of the Queensland Museum* **52**(2): 149–202. Brisbane. ISSN 0079-8835.

Five species of small (≤15 mm total length) grass cicadas are described in *Graminitigrina* gen. nov., of the subfamily Cicadettinae, Tribe Cicadettini. Three species occur in northern Queensland, two of which, *G. karumbae* sp. nov. and *G. bowensis* sp. nov., have distributions spanning linear distances of approximately 655 and 830km respectively. The third, *G. triodiae* sp. nov., is restricted to the Burra Range within White Mountains National Park. Two species, *G. bolloni* sp. nov. and *G. carnarvonensis* sp. nov., occur in southern to central Queensland; *G. carnarvonensis* restricted to the Mount Moffatt-Chesterton Range region of Carnarvon National Park, and *G. bolloni* within the area between Bollon, 60km north of St George, to near Jericho, spanning a linear distance of approximately 505km. The calling songs of each species are shown to be distinct, and constitute valuable taxonomic characters. Additional song types recognised and documented are: the 'alarm (stress) song', the 'short song' (both types recorded from *G. bowensis*) and the 'ratchet song', this common to four of the species described here. The calling song of *G. bowensis* is shown to vary in some temporal characteristics over at least part of its known distribution. ❐ *Cicadas, calling songs, chirping songs, Queensland, song analyses, taxonomy.*

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This work results from ongoing systematic collecting of cicadas throughout Queensland. Such surveys continue to uncover previously undescribed smaller cicadas occurring in a wide range of woodland and grassland habitats (e.g. Ewart, 2005). An important adjunct of the collection of specimens is the aural recording of their songs, which are valuable taxonomic tools (e.g. Young, 1972; Ewart, 1988, 1989, 1998, 2005; Ewart & Popple, 2001; Popple, 2003; Simões et al., 2000; Sueur, 2002; Pinto-Juma et al., 2005; Quartau & Simões, 2006; Seabra et al., 2006). In the field, calling songs provide an efficient means for identifying known species, and recognition of new species and species complexes. This paper describes five new and very distinctive species that are confined to rough grassland, low heath and spinifex, commonly associated with open forest, and which belong to a new genus. The distances over which the two most northern species have been collected, and aurally recorded, provide useful data in evaluating possible regional variation in morphology and song characteristics.

ABBREVIATIONS. *Institutions.* ANIC, Australian National Insect Collection, Canberra; AE, private collection of A. Ewart, Caloundra; BMNH, the Natural History Museum, London; JM, private collection of J. Moss, Brisbane; KLD, private collection of K. L. Dunn, Canberra; LWP, private collection of L.W. Popple, Brisbane; MSM, private collection of M.S. Moulds, Kuranda; QM, Queensland Museum, Brisbane. *Collectors and general.* NP, National Park; Rd, Road; Rec, recorded (= aural/electronic song recording); sp, species; spec and Spm, specimen; CB, C.J. Burwell; AE, A. Ewart; BJM, B.J. Moulds; MSM, M.S. Moulds; LWP, L.W. Popple. *Morphological.* BL, total body length; FWL, fore wing length; HW, head width; PW, pronotum width; AW, abdomen width; FWL/BR, fore wing length/breadth ratio.

MATERIALS AND METHODS

Anatomical terminology follows Moulds (2003, 2005) for general body shape and wing characters, Dugdale (1972) and Moulds (2005) for genitalia, de Boer (1999) for opercula, and Simmons and Young (1978), Dugdale (1972) and Bennet-Clark (1977) for timbals. The timbal long ribs are referred to sequentially as ribs numbered 1 to 5, with rib 1 being the most posterior (adjacent to timbal plate). The higher

TABLE 1. Comparison of selected morphological characters, with specific reference to males, of genera most similar to *Graminitigrina*

Genera	*Graminitigrina*	*Pauropsalta*	*Cicadetta celis*+ (Type sp. new genus)	*Urabunana marshalli*+ (Type sp. new genus)	*Pauropsalta basalis*+ (Type sp. new genus)	*Pauropsalta eyrei*+ (Type sp. new genus)
Total body length (mm) (♂ and ♀)	10.7-15.0	11.7-24	12.5-26	9.0-16	10.7-12.4	13.2-23.4
Abdomen:						
(i) General shape (dorsal view)	Slightly to distinctly bulbous (anteriorly)	Gently tapered distally*	Gently tapered distally from tergites 2 to 8*	Slightly bulbous between tergites 2 to 4 (or 5), tapering rapidly thereafter*	Relatively even from tergites 2 to 6, tapering in rounded outline rapidly thereafter	Relatively gentle narrowing between tergites 2 to 6 (or 7), thereafter narrowing rapidly, especially at tergite 8.
(ii) Lateral width of tergite 3 relative to between auditory capsules	Slightly wider (most common) to nearly equal	Similar width	Slightly narrower in width*	Approximately equal	Slightly wider	Similar width
(iii) Colour	Yellow, pale yellow brown, reddish brown with conspicuous dorsal black fascia	Predominantly black ± reddish-brown to yellow-brown along tergite posterior margins*	Orange, yellow-brown, pale to medium brown	Variable; pale brown, orange yellow, green; black dorsal fascia in non-black species	Predominantly pale brown to reddish brown*	Pale brown to orange, yellow-orange; pale green
(iv) Width across auditory capsules relative to lateral pronotal margins	> than pronotum	Similar to, or slightly > than pronotum	Similar to, or slightly wider than pronotum	> than pronotum	> than pronotum	Approximately equal*
Head:						
(i) Width (including eyes) relative to lateral pronotal margins	Similar width	Similar to, or slightly wider than pronotum	Slightly wider than pronotum*	Maybe both < or > than pronotum width	> pronotum*	> pronotum*
(ii) Rostrum length(relative to coxae)	Extend to posterior margin of mid coxae	To mid coxae or just beyond mid coxae	Extend to hind coxae*	Just beyond mid to near hind coxae*	Reaches almost to hind coxae*	Reaches to base of mid coxae
Hind wings:						
(i) Number of apical cells	5 (less commonly 4)	5 (less commonly 6)	6 (rarely 5)*	4 to 6 (variable), 5 most common	5	6*
(ii) Infuscations (brown)	Weak within area of plaga (in anal lobe)	Small, distinct at distal end of vein 2A extending to wing margin*	None*	None*	Weak adjacent to distal end of vein 2A, extending either side along anal lobe margin, also in plaga	Absent to extremely faint adjacent to distal termination of vein 2A and adjacent margins
(iii) Size of anal lobe relative to cubital cell 1	Markedly wider than cubital cell 1	Much wider than cubital cell 1	Wider than cubital cell 1, but not markedly so*	Similar in breadth, or slightly broader than cubital cell 1*	Much wider than cubital cell 1	Much wider than cubital cell 1
Opercula:						
(i) General shape and curvature inwards towards abdominal midline	Rounded along distal to medial margin; tends to be elongated, and inward-ly curved towards midline	Somewhat elongated, terminally rounded, inclined inwards to abdominal midline	Somewhat elongated and sickle-shaped, markedly curved inwards to midline distally; markedly undulated*	Broad and rounded along medial to distal margins*	Broad, strongly inclined inwards towards midline; moderately acutely rounded distally*	Relatively elongated and curved along distal to medial margins towards midline; narrowed rounded termination*
Timbals:						
(i) Fusion of long ribs ventrally	1 to 3 most common (1 to 4 less common)	0 to 4 (most commonly 2 or 3)	1 to 2 nearly fused, or completely fused*	1 to 3 fused or unfused	Not fused*	1 to 2 fused (rarely 1 to 3)
(ii) Fusion of long ribs to basal spur	1 to 3 fused	Usually 1 to 4 (rarely 1 to 2 or 3) fused	1 to 4 fused*	1 to 3 always fused; 4 also commonly fused	1 to 3 fused	1 to 4 fused*

Table 1 continued...

Genera	*Graminitigrina*	*Pauropsalta*	*Cicadetta celis*+ (Type sp. new genus)	*Urabunana marshalli*+ (Type sp. new genus)	*Pauropsalta basalis*+ (Type sp. new genus)	*Pauropsalta eyrei*+ (Type sp. new genus)
Genitalia: (i) Claspers	Robust; sharp, pointed hooked terminations; not clearly exposed outside pygofer in lateral view	Well developed, robust, terminally hooked processes; not always visible outside pygofer in lateral view	Robust; in ventral view tapering to a blunt point, apically wide part, basally adjacent	Very robust, protruding in lateral view; terminally hooked*	Relatively small, only just visible in lateral view, hooked terminally*	Somewhat robust, small hooked claspers, not clearly exposed outside pygofer lateral view
(ii) Upper pygofer lobes	Enlarged extended posteriorly beyond pygofer; terminations tend to curve dorsally	Upper lobes enlarged, undivided, and flat	Significantly elongated laterally along pygofer, as finger-like (flattened or cylindrical) processes, rounded terminally*	Conspicuous, rounded, not markedly extended*	Bifurcate, extended ventrally, the lower part tooth-like and sharply pointed*	Extended into blinker- like processes with flattened termination in lateral view
(iii) Lower pygofer lobes	Clearly developed, rounded in lateral view, with inward pointing flat triangular extensions	Clearly developed	Robust, elongated along pygofer margin, rounded on outer margins, concave on inner margins; clearly separated from upper lobes*	Clearly visible in lateral view, smaller than upper lobes*	Present; but subdued in lateral view, gently curved*	Conspicuous, acutely to sharply tapering and posteriorly pointing.
(iv) Inner pygofer lobes	Prominent, somewhat rounded and bulbous	Distinctly developed	Not clearly developed in lateral view*	Clearly developed, broadly rounded, visible in lateral view	Strongly developed, acutely tapering, declivious, posteriorly inclined*	Slightly to conspicuously bulbous and raised in lateral view
(v) Dorsal beak	Inconspicuous	Acute, prominent, pointed apically*	Prominent, acute, pointed apically*	Very strongly developed, curved in lateral view*	Strongly developed, downward curving in lateral view, sharply pointed*	Prominent, sharply pointed, slightly curved in lateral view*
(vi) Aedeagus, endotheca	Long sclerotised endotheca, curved (to broad U-shape in some species), ornamented apically	Long sclerotised endotheca, often apically ornamented*	Theca recurved distally into an exaggerated U-shape*	Endotheca broad tube-like, straight to very gently curved in lateral view; no ventral support*	Endotheca gently curved*	Gently curved endotheca, apically enlarged and ornamented with a collar-like process and/or simple spines*
(vii) Pseudoparameres	Inconspicuous to absent	Usually prominent, joined to endotheca near base, often extending apically beyond endotheca*	Slender, delicate and long; aligned broadly with aedeagus*	Short and very broad in lateral view; joined to apex of endotheca*	Curved, apically tapering, attached dorsally and sloping ventrally across endotheca; longer than endotheca*	Dorsal, similar or shorter in length to endotheca; joining endotheca near basal plate, bifurcate and outward curving; distally tapering, acutely pointed*
Habitat:	Grassland, low heathland, usually associated with open woodland	Open woodland; inhabiting low to high branches*	Open woodland, especially in canopy*	Grassland, open and within open woodland	Low open woodland, shrubland, rough grassland	Open woodland, including urban*

+ These represent the type species of new genera proposed by M.S. Moulds (in prep, 2008). *Characters that differ from those of *Graminitigrina*

classification adopted in this paper follows Moulds (2005).

Measurements (in mm) are given as ranges and means (in parentheses). The head width is taken across the outer margins of the compound eyes; the pronotum width is the maximum width across the lateral margins; the abdomen width is measured across the auditory capsules. Fore wing length/breadth ratios are based on maximum lengths and breadths.

SONG RECORDINGS AND ANALYSES. A number of recordings were made of single insects placed within plastic containers, 16.5 x 16.5 x 9.5cm in size, in which were inserted small quantities of the grasses on which the insects were captured. A fine white cloth covering was placed over the top of the boxes, with strong artificial lighting (not fluorescence) immediately above. The lighting provided additional heat, and calling songs were usually readily induced from the insects. Temperatures within the containers were consistently 30-35°C during normal summer conditions. The recording microphone (Sennheiser model K6/ME66) was placed immediately above the containers, and recordings mostly made with a Sony Walkman cassette recorder WM-D6C model, using metal tapes; this recorder responds to near 18 kHz, with a linear response to at least 15 kHz.

The primary reasons for making recordings within containers relates to the highly wary behaviour, aurally soft songs, and sometimes erratic singing patterns of the described species, which make it impractical to place a microphone close enough, for long enough, to directly record meaningful song segments. This problem was in part circumvented in two species by use of a parabola (Telinga model with Telinga PRO 5 "Classic" microphone) allowing direct field recordings, and also by use of a collapsible, cylindrical net cage (38cm long by 30cm diameter) hung from convenient vegetation in the field. For *G. carnarvonensis*, a Sony Minidisk recorder MZ-NH900 was used in PCM recording mode using the net cage. Alarm (stress) songs of *G. bowensis* were recorded from two locations when the insects were trapped in spider webs, and also constrained in a net. The direct field recording of the *G. bolloni* calling song (at Jericho, central Queensland) was made by L.W. Popple using a Marantz PMD670 Solid State recorder in conjunction with a Telinga parabola and PRO 6 microphone.

All computer analyses were performed by initial digitising through 16-Bit Terratec or SB Audigy 2ZS sound cards at 44.1 kHz sampling frequency, followed by processing with Avisoft SAS Lab Pro 4 software. Reverberation effects in container recordings have been recognised for some sharp pulses at time scales of ≤1ms, causing some broadening of the pulses. An additional effect seen in some container recordings is the enhanced splitting of the dominant frequency peaks of the amplitude (and power) spectra into distinct frequency bands. As this is also evident in some field recordings, it is considered to be a real characteristic of some songs. This effect does, however, appear to be enhanced in container recordings, although not affecting the dominant frequency measurements (see below). Amplitude spectra were produced using a 556-point Fast Fourier Transform with Hamming window.

The amplitude/power spectra of *Graminitigrina* cicada songs, as in other cicadettine cicadas (e.g. *Crotopsalta*, Ewart, 2005), are complex with multiple distinct peaks occurring within the normally well defined envelope defining the dominant frequency maxima range. The individual peak amplitudes (although not frequencies) within this envelope are typically variable between songs of different insects of the same species. In order to determine a more reproducible frequency maximum for each spectrum, a "dominant frequency" parameter is used, this being the mean frequency of the total amplitude dominant frequency envelope as seen in the spectra. The extent of this envelope is shown in the amplitude spectra presented. This method allows more reproducible estimates of dominant frequencies, and also compensates for enhanced frequency splitting that may accompany container recordings. In addition to dominant frequencies, the amplitude spectra illustrated also list measured sideband frequencies (e.g. Bradbury and Vehrencamp, 1998). These are derived manually from frequency expanded segments of the spectra, using the automatic measuring cursors available in the Avisoft software. Sideband frequencies below about 300 Hz are reproducible in spectra from the same species. Above this frequency, the measured frequencies become progressively less reliable due to uncertainties in their correct identification and significance.

Following Ewart (2005), a modified terminology of Ragge and Reynolds (1998) is adopted for the description and analyses of the songs. Although the Ragge-Reynolds terminology was designed for orthopteran insects, there are

FIG. 1. *Graminitigrina bowensis* sp. nov. Dorsal view. Flagstaff Hill, Bowen. Total body length 13.7mm.

sufficient similarities in song structures to warrant extending the terminology to the cicada songs described here. The term **syllable** is used for discrete but relatively short (≤20 ms) pulse groupings that plausibly result from a single buckling movement (in and/or out) of one timbal, or both if synchronous; if the two timbals buckle alternately, without a time gap between, then two syllables may occur juxtaposed, as is believed to occur in clicking phases within some of the cicadas described here. The same result may be attained, at least in principle, by a discrete inward, followed immediately by an outward click of a timbal; where, however, a small but discrete gap does occur in such a sequence between the syllables, the term **diplosyllable** is normally used for these syllable pairs. The term **echeme** is applied to the first order assemblage of syllables produced during continuous, repetitive buckling of the timbal pairs (i.e. ≥2 cycles of buckling without significant pause). Where two (or sometimes more) syllables are juxtaposed, these are termed **macrosyllables**, and are identified as echeme components in some songs described here. Time expanded waveform and envelope plots reveal that the syllables are resolved into smaller (higher frequency) pulse groupings, here termed **hemisyllables**, although the precise resolution of these is sometimes ambiguous. The hemisyllables, with further time expanded detail, can be resolved into even higher frequency pulses, representing the fundamental frequency carrier waves of the song.

SYSTEMATICS

Family CICADIDAE Latreille

Subfamily CICADETTINAE Buckton

Tribe Cicadettini Buckton

Graminitigrina gen. nov.
(Table 1)

TYPE SPECIES. *Graminitigrina bowensis* sp. nov.

INCLUDED SPECIES. *G. bowensis* sp. nov.; *G. karumbae* sp. nov.; *G. bolloni* sp. nov.; *G. carnarvonensis* sp. nov.; *G. triodiae* sp. nov.

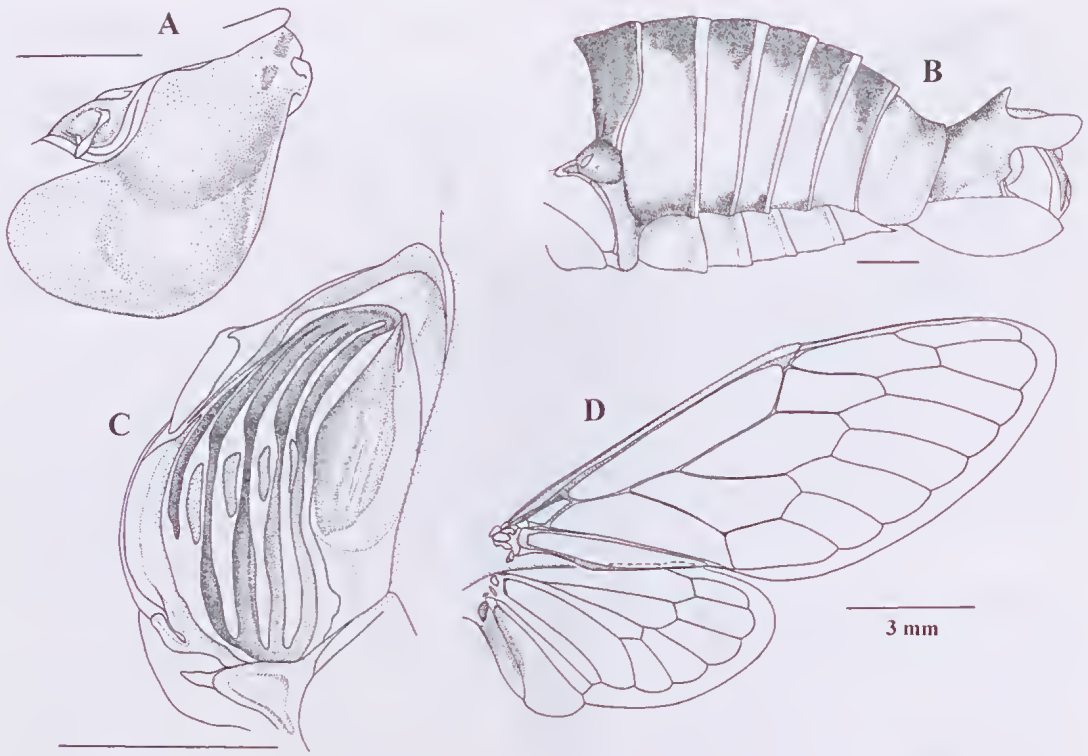

FIG. 2. *Graminitigrina bowensis* sp. nov. Flagstaff Hill, Bowen. A, right operculum; B, lateral abdomen; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

ETYMOLOGY. From the Latin *gramen* meaning grass, and *tigri-n* meaning tiger-like colouration. These together describe the cicadas as 'grass tigers', referring to their grassy habitat and conspicuous yellow-orange and black dominant colouration.

DIAGNOSIS. Very small cicadas, 10.7-15mm total body length. Head and thorax predominantly black and of similar width, except ampliated (outwardly curved) lateral angles of pronotal collar projecting beyond outer margins of compound eyes. Abdomen dominantly yellow/yellow-brown/reddish to orange-brown, with dark brown to black dorsal patches along tergites, which give overall appearance of a dark longitudinal fascia. Male abdomen in dorsal view slightly bulbous anteriorly; width across tergite 3 subequal or slightly greater than width across auditory capsules; width across auditory capsules greater than (males) or similar to (females) width across lateral margins of pronotal collar. Sternites strongly convex, projecting below tergites in lateral view; abdominal venter lacking a medial darker fascia; sternite II with small, usually black, medial depression. Compound eyes clearly separated from pronotum along their outer ventral margins; distance between lateral ocelli slightly less than, to equal to, distance between lateral ocellus and compound eyes. Rostrum extending to posterior margins of mid coxae, but not clearly beyond. Fore wing hyaline, relatively short and broad with length/breadth ratios between 2.40-2.68 (mean ratios for different species between 2.45-2.60); fore wing similar in length to total body length; pterostigma pale brown to pale red-brown; costal vein relatively even in width, with minor thickening proximally and slightly more pronounced thickening adjacent to node; costal vein very gently curved anteriorly; sclerotised area along anterior margin of costal vein very narrow and much thinner than costal vein thickness; costal and R+Sc veins fused; CuA intersecting M well beyond basal cell so that length of first section of inner margin of radial cell is one half to equal length of second section; 3 distal vein sections of M, that form inner margin of radial cell, unequal in length; cubital and medial cells of roughly similar size; 8 (very rarely 9) apical

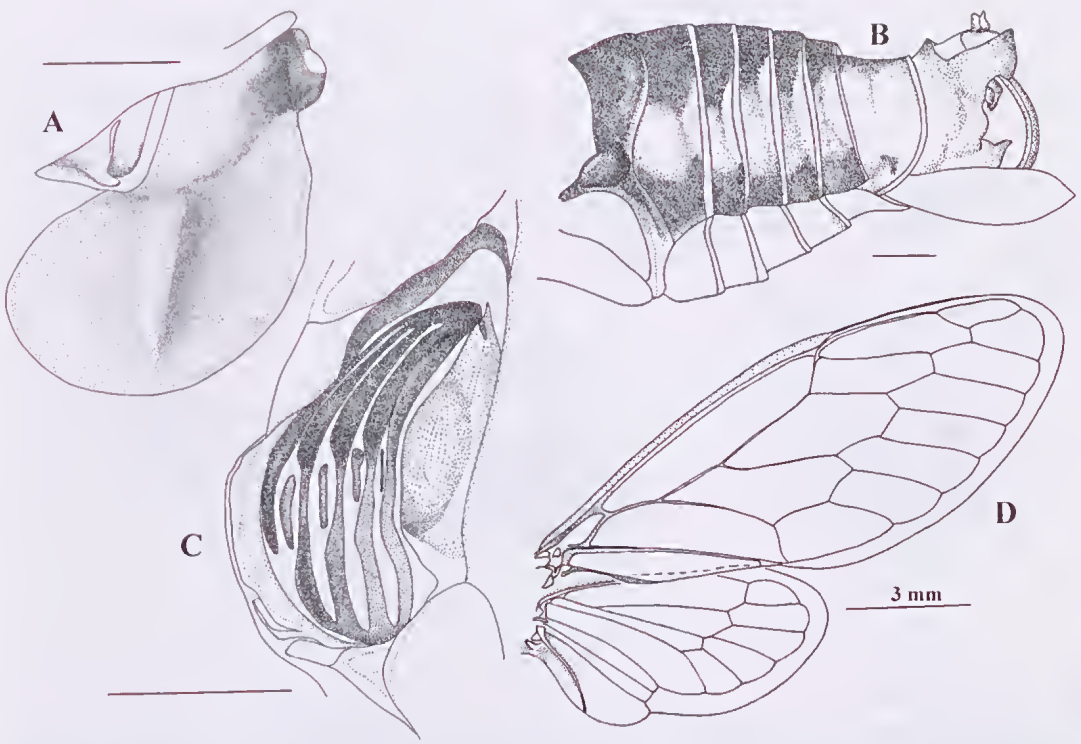

FIG. 3. *Graminitigrina bowensis* sp. nov. Einasleigh River crossing, 35km W. Mt Surprise. A, right operculum; B, lateral abdomen; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

cells that are approximately equal in length to ulnar cells (some longer, some shorter); basal membrane off-white opaque. Hind wings hyaline with 5, less commonly 4, apical cells; weak brown infuscation within anal cell 1; anal lobes markedly broader than cubital cell 1. Fore femora with 3 prominent erect spines, small additional spine distally in some specimens. Opercula moderately elongated roughly parallel to abdomen, more or less confluent with distal margin of tympanal cavity, normally very slightly overlapping distal tympanal margin; opercula inwardly curved towards abdominal midline in medial-distal area, distal and medial margins of opercula broadly rounded; broad dome developed across basal area towards crest; inner margins of operculae well separated; opercula of males developed asymmetrically around meracantha. Timbals with 5 well developed long ribs, the 5th rib reduced in length; ribs 1 to 3 fused ventrally and dorsally to well developed basal spur; 4 (less often 3) well developed short ribs; well developed dome on timbal plate with shallow and nearly vertically oriented grooves centrally. Pygofer with prominent, extended upper lobes which dominate pygofer between inner lobe (secondary basal lobe) and dorsal beak, these nearly flat with gently undulating and concave curvature on inner faces; in lateral view, upper lobes broad, paddle-shaped, often decurved, and extending to or beyond anal styles; clearly developed lower lobes with small inward pointing triangular extensions; prominent rounded inner lobes, roughly triangular in shape and visible in lateral view; well developed robust claspers with sharply-pointed, hooked terminations, not always protruding outside pygofer in lateral view; dorsal beak inconspicuous; median lobe of uncus small, duck-bill shaped, not dominant; theca characteristically long and sclerotised, curved and often terminally ornamented, protruding from pygofer; pseudoparameres small to absent; aedeagal basal plate undulated in lateral view, broadly Y-shaped in dorsal view, with functional membranous 'hinge'.

Table 1 provides a comparative summary of selected morphological characters of related genera which may be superficially confused with *Graminitigrina*.

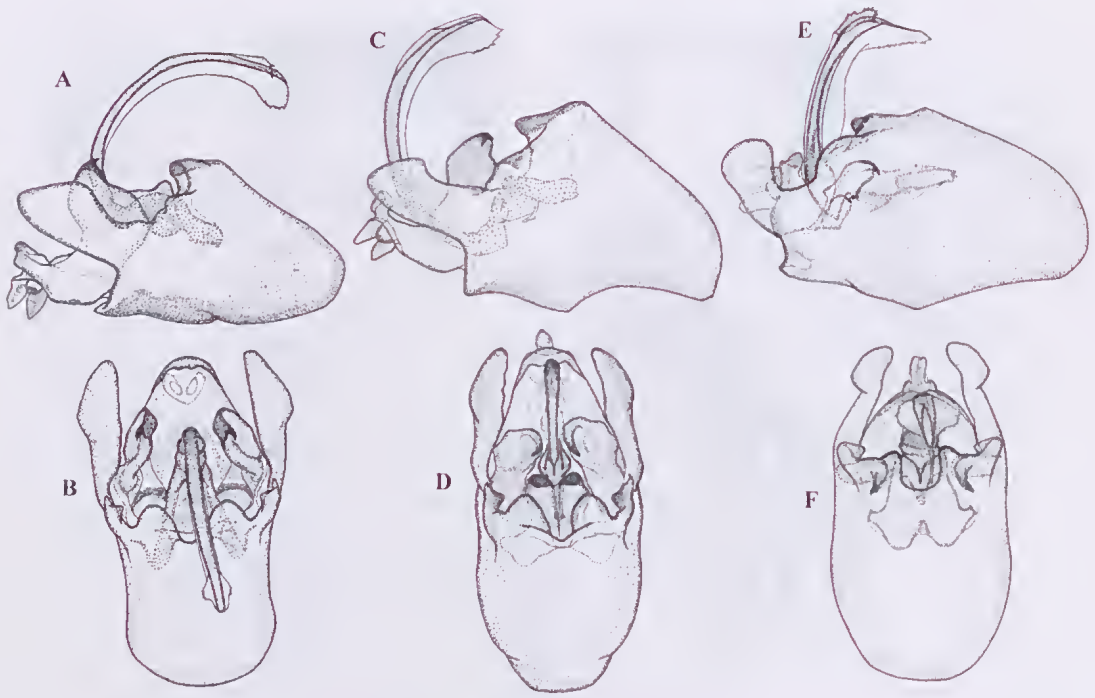

FIG. 4. *Graminitigrina bowensis* sp. nov. Pygofer and male genitalia, lateral (top) and ventral views (bottom). Specimens from Bowen (A, B); 58km SE Mt Surprise (C, D); Slaty Creek, S.W. Cloncurry (E, F). Length of pygofers, 3.3, 3.2 and 3.1mm, respectively.

KEY TO SPECIES OF *GRAMINITIGRINA* (Based on males)

1. Timbal rib 5 (anterior rib) extending ventrally at least to dorsal end of adjacent anterior short rib, usually extending along half the length or more of short rib (Figs 2C, 3C, 6C, 7C); aedeagus with long theca recurved into broad U-shape with thin sclerotised wafer-like process, usually finely serrated, along inner curved surface; pseudoparameres absent (e.g. Figs 4A, 8A) 2

   Timbal rib 5 not extending ventrally to dorsal end of adjacent anterior short rib (Figs 9C, 13C) or anterior short rib absent (Fig. 11C); aedeagus with long, variably curved to recurved theca, also with thinly developed wafer-like process developed along inner curved surfaces; pseudoparameres present but sometimes small (Figs 10A, 12A, 14A).....3

2. Timbal rib 5 extending ventrally along anterior short rib from about a half to its entire length; no ventrally located short remnant of rib 5; rib 5 very close to, or partially in contact with dorso-anterior timbal margin (Figs 2C, 3C); maximum width across abdominal tergite 3 slightly greater than across auditory capsules; abdominal tergite 2 almost entirely black (Figs 2B, 3B).....*G. bowensis*

   Timbal rib 5 extending ventrally along anterior short rib to at most half its length, often less, but with a isolated remnant of rib 5 located ventrally; rib 5 close to, but not in contact with dorso-anterior timbal margin (Figs 6C, 7C); maximum width across abdominal tergite 3 similar to width across auditory capsules; abdominal tergite 2 not entirely black.....*G. karumbae*

3. Fore wings without obvious apical infuscation (Figs 9D, Pl. 2A); aedeagus gently curved except distal part of theca strongly recurved, hook-like; sclerotised wafer-like process on theca either absent or only developed apically .....*G. bolloni*

   Fore wings with weak to distinct infuscation apically (Figs 11D, 13D, Pl. 2C, E); aedeagus with gently curved theca, apex not strongly recurved; apex of theca either finely serrated or with complex sclerotised ornamentation (Figs 12A, 14A).....4

4. Fore wings with weak brown infuscation apically, extending from approximately apical cell 4 (Figs. 11D, Pl. 2C); 3 short timbal ribs between ribs 1 to 4 clearly developed, no short rib anterior to long rib 4; timbal rib 4 not fused ventrally to ribs 1-3 (Fig. 11C); prominent spikes on meracantha (Fig. 11A); aedeagus very gently curved and apically ornamented (Fig. 12A) *G. carnarvonensis*

   Fore wings with clearly developed apical infuscation extending (more weakly) to apical cell 5 and ulnar cells 1 and 2 (Figs 13D, Pl. 2E); timbal rib 4 fused ventrally to ribs 1-3; short timbal ribs between ribs 1 to 4 weakly developed; unusually large area of white resilin developed anteriorly to ribs 4 and 5 (Fig. 13C); meracantha spikes short (Fig. 13A); aedeagus with more strongly curved theca, apex slightly sinuous and unornamented *G. triodiae*

Graminitigrina bowensis sp. nov.
(Figs 1-5, 15-24, Plate 1A–E, Table 2)

MATERIAL. HOLOTYPE: ♂, QMT133332, Flagstaff Hill, Bowen. NQ., 4 Mar 2003, AE, 20°00.93'S 148°15.97'E, Photog. Spm PS1048. PARATYPES: NORTH QUEENSLAND: 2♂, Flagstaff Hill, Bowen, Grass, 13.ii.1998, AE, 20°00.88'S 148°15.96'E, Recorded; 1♀, same data; 1♂, same data, 10.ii.1999, Recorded; 1♀, same data; 15♂, same data, 26.ii.2000; 1♂, same data, Recorded Specimen 1; 1♂; same data, Recorded Specimen 2; 1♂, Flagstaff Hill, Bowen, 7.ii.2002, 20°00.86'S 148°15.94'E; 2♂, Flagstaff Hill, summit area, Bowen, AE, 2.ii.2006. 20°00.93'S 148°15.97'E; 1♂, same data, Recorded (alarm eall); 1♂, same data, 9.ii.2006; 1♂, E. side Einasleigh R., ~35km W. Mt Surprise, AE, 27.ii.2003, 18°11.15'S 144°00.77'E, Recorded; 1♂, same data, 2 iii.2003, Recorded; 1♂, 39.5km WNW Greenvale, (11.9km SE of Lynd jct., Lynd Hwy), Grass, AE, 3.iii.2003, 18°56.73'S 144°38.68'E; 1♂, Water Reserve, Croydon, NQ, Low Trees, AE, 28.i.2005, 18°11.35'S 142°14.61'E, Recorded; 1♂, 40.1km SSW Mt Surprise/Lynd Hwy. Jct., NQ, Grass, AE, 3.iii.2003, 18°28.93'S 144°44.79'E; 13♂, 5♀, 40.0km SSW Lynd-Mt Surprise Rd Jct., NQ, Grass, AE, 31.i.2005, 18°28.97'S 144°44.80'E; 1♂, same data, Recorded; 1♀, 49.4km SSW Mt Surprise/Lynd Hwy. Jct., NQ, Grass, AE, 3.iii.2003, 18°33.79'S 144°44.42'E (AE). 1♂, Flagstaff Hill, Bowen, 10.ii.1999. AE. 20°00.88'S 148°15.96'E; 1♀, Flagstaff Hill, summit area, Bowen, AE, 9.ii.2006. 20°00.93'S 148°15.97'E (ANIC). 1♂, Flagstaff Hill, summit area, Bowen,, AE, 9.ii.2006. 20°00.93'S 148°15.97'E (BMNH). 1♂, Flagstaff Hill, summit area, Bowen, AE, 9.ii.2006. 20°00.93'S 148°15.97'E; 11♂, 13♀, Slaty Creek, S. of Cloncurry, 6.i.2001, 20:53:19S 140:20:45E, MSM and BJM (MSM).

DESCRIPTION (MALE). Figs 1-4, Pl. 1A–D. *Head.* Supra-antennal plate, vertex, mandibular plate and genae predominantly shiny black, covered by short golden pubescence (supra-antennal plate only) and longer yellow-silver pubescence; pale sandy-brown triangular fascia extending posteriorly from median ocellus, widening towards and extending to pronotal margin; small pale sandy-brown patches on antennal pedicels extending laterally along anterior margin of supra-antennal plate to postclypeal margin. Ocelli rose-red. Compound eyes dark brown. Postclypeus shiny black with sandy-brown margin extending around frons. Anteclypeus shiny black; rostrum brown grading to black apically. Antennae predominantly black with sandy-brown bases and brown apices.

Thorax. Pronotum shiny black, covered with patchy short silvery pubescence; ventro-lateral margins pale sandy-brown, broad pale sandy central fascia extending posterioly from near anterior margin, splaying out and fusing with pale sandy-brown pronotal collar; lateral angles of pronotal collar markedly ampliate, black with pale sandy-brown margins. Mesonotal submedian sigillae black, short, completely coalesced medially; narrow black fascia extending posteriorly from coalesced sigillae, progressively broadening and filling area between anterior arms of cruciform elevation (including scutal depressions), further bifurcating and extending as a narrow curved fascia between anterior and posterior arms of cruciform elevation; small pale central spot within fascia between anterior arms; lateral sigillae black, roughly triangular, posteriorly rounded, not reaching apices of anterior arms of cruciform elevation; margins of wing grooves, cruciform elevation, and areas surrounding lateral sigillae sandy-brown; mesonotum with sparse short silver pubescence, particularly strong near wing grooves

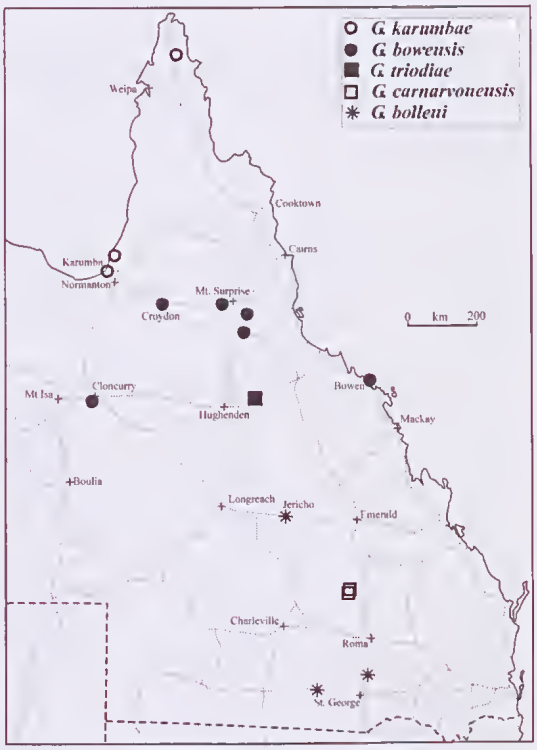

FIG. 5. Distribution records of the five described species of *Graminitigrina* in Queensland.

Wings. Venation pale off-white to pale brown, becoming darker brown apically; very narrow sclerotised brown anterior margin to costal vein. Hind wing with white opaque plaga extending along margins of veins 3A and 2A, but no

TABLE 2. *Graminitigrina bowensis* - summary of song parameters. Data compiled from separate recordings from seven insects (Bowen; field and container recordings), two insects (58km SE Mt Surprise; field and container recordings) and one insect from remaining localities (container recordings).

Locality	Bowen	Bowen	Bowen	Croydon	58 km SE Mt Surprise		Einasleigh River Crossing	11.9 km SE of 'The Lynd' Hwy Jct.
Song Type	Calling Song	Stress Song[5]	Ratchet Song[5]	Calling Song	Calling Song	Stress Song[5]	Short Song	Short Song
1. Extended ecneme ("buzzing")								
Total length (s)	1 to 4.5	-	-	-	-	-	-	-
Macrosyllable lengths (ms)	10.8(10.3-11.3)[1]	-	-	-	-	-	-	-
Syllable lengths (ms)	4.4-6.3	-	-	-	-	-	-	-
Hemisyllable Lengths (ms)	1.0(0.35-1.9)[1]	-	-	-	-	-	-	-
2. Post-extended ecneme phrases for								
Bowen locality: 'Normal' (standard) songs for nther localities								
(a). Chirp phrases (short ecnemes + associated clicks)								
Repetition rates (s^{-1}): Container	1.9(0.9-2.8)[1]	-	-	0.92(1.3-0.50)	1.8(1.2-2.4)	-	0.78(1.7-0.49)	0.79(1.9-0.45)
Repetition rates (s^{-1}): Field	2.9(2.2-3.3)[1]	15.3(8-28)	-	-	-	21.7(18-29)	-	
No. of initial clicks per chirp: Container	2.8(0-5)[1]	-	-	8.4(0-21)	2.2(0-4)	-	0.2(0.4)	0
No. of initial clicks per chirp: Field	3.2(2-5)[1]	-	-	-	-	-	-	-
Chirp lengths (s): Container	0.34(0.15-0.46)[1]	-	-	0.61(0.24-1.6)	0.20(0.13-0.24)	-	0.71(0.33-2.0)	0.76(0.21-1.7)
Chirp lengths (s): Field	0.24(0.18-0.33)[1]	0.031(0.009-0.044)	-	-	-	0.026(0.008-0.042)	-	-
(b). Single click phrases (single discrete macrosyllables)								
Macrosyllable lengths (ms)	13.7(12.7-14.4)[1]	10.8(10.6-11.0)	10.0(9.2-11.5)	11.3(11.1-11.4)	10.9(8.9-11.6)	9.5(9.1-9.9)	13.7(11.2-15.1)	-
Syllable lengths (ms)	6.1-7.2	4.9-6.0	4.5-6.5	5.3-5.8	5.4-6.2	4.4-5.3	6.7-7.2	-
Hemisyllable lengths (ms)	1.3(0.83-1.7)[1]	1.4(0.73-2.6)	1.2(0.92-1.4)	1.3(1.2-1.9)	1.3(1.0-1.6)	1.4(0.89-2.0)	1.5(1.3-2.2)	-
Interval between first two doublet pulses[2]	4.1(3.0-5.2)[1]	3.7(3.6-3.9)	3.6(3.3-4.0)	3.9(3.4-4.1)	4.1(3.9-4.2)	3.4(3.3-3.5)	4.6(4.2-5.0)	-
Click repetition rates (s^{-1})	20-59	-	20-35	30-56	26-56	-	34-56	-
(c) Short ecneme (chirp) phrases								
Macrosyllable lengths (ms)	10.2(10.0-10.5)[1]	11.0(10.7-11.4)	-	9.0(7.5-10.4)	10.9(10.7-11.9)	9.3(8.8-9.8)	12.5(10.4-16.4)	11.2(10.5-12.9)
Syllable lengths (ms)[3]	4.6-5.7	4.9-6.3	-	3.7-5.1	5.0-5.7	4.2-5.0	5.1-6.1	4.6-5.8
Hemisyllable lengths (ms)	1.4(0.66-2.0)[1]	1.4(0.96-2.6)	-	1.2(0.95-1.4)	1.2(0.91-1.6)	1.5(0.78-2.0)	1.4(0.94-1.9)	1.1(0.88-1.6)
3. Pre-extended ecneme phrases for Bowen locality								
(a) Chirp phrases (short ecneme + associated clicks)								
Repetition rates (s^{-1})	2.0(2.5-1.5)[1]	-	-	-	-	-	-	-
No. of clicks between short ecnemes	7-10	-	-	-	-	-	-	-
Short ecneme lengths (s)	0.30(0.21-0.49)[1]	-	-	-	-	-	-	-
Click repetition rates (s^{-1})	40.5(26-59)[1]	-	-	-	-	-	-	-
(b) Single click phrases (single discrete macrosyllables)								
Macrosyllable lengths (ms)	13.4(13.0-14.1)[1]	-	-	-	-	-	-	-
Syllable lengths (ms)[4]	5.1-8.2	-	-	-	-	-	-	-
Hemisyllable lengths (ms)	0.66-1.8	-	-	-	-	-	-	-
Interval between first two doublet pulses	4.3(3.9-4.7)[1]	-	-	-	-	-	-	-
(c) Short ecneme phrases								
Macrosyllable lengths (ms)	10.1(9.6-10.7)[1]	-	-	-	-	-	-	-
Syllable lengths(ms)[3]	3.8-5.5	-	-	-	-	-	-	-
Hemisyllable lengths (ms)	0.39-1.9[1]	-	-	-	-	-	-	-
4. Dominant frequency (kHz)	13.12 (12.64-13.56)	11.81	12.34	13.06	14.23	13.92	14.72	14.00

(1) Figures are means and (ranges). (2) See Figs. 19c, d and 21c, d for doublet definitions. (3) Two per macrosyllable. (4) Two to three per macrosyllable. (5)Field recordings.

associated brown infuscation; 4 (less common) to 5 apical cells.

Legs. Fore coxae predominantly pale to medium brown with lozenge-shaped black to deep brown fasciae located centrally on lateral and anterior faces; mid and hind coxae pale to medium sandy-brown with localised deep brown to black patches subdorsally on lateral faces; fore and mid trochanters and femora sandy-brown to brown with narrow, medium to dark brown longitudinal fasciae; hind femora mainly pale brown; fore tibiae and tarsi medium to dark brown on anterior faces, pale sandy-brown on posterior faces; mid and hind tibiae and tarsi mostly pale sandy-brown to pale brown; claws pale brown, dark brown apically.

*Operc*ula. Gently and broadly rounded along distal and medial margins, medial margin markedly curved inwards toward abdominal midline; colour sandy-brown except for 2 small, medium brown patches near basal crest of each operculum; basal area and lateral part of distal area of operculum very gently domed and longitudinally ridged, roughly parallel to midline of abdomen; spikes on mercantha small, not clearly overlapping opercula plate; distal operculum only just extending to anterior margin of sternite II in lateral view.

Timbals. Long ribs 1-3, (and usually 4) fused ventrally, and also dorsally to basal spur; rib 5 very close to and partly in contact with dorso-anterior margin of timbal; rib 5 extending ventrally to at least half way along (Slaty Creek specimens) or along entire length of adjacent, prominent anterior short rib; 4 clearly defined short ribs; dome on timbal plate with ridges (roughly parallel to ribs).

Abdomen. Maximum width across tergite 3 slightly greater than width across auditory capsules; in dorsal view, abdomen evenly decreasing in width from tergites 3-8. Dominant tergite colouration sandy/orange-brown, with reddish-brown colouration along the submedial to dorsal posterior margins adjacent to, but not extending across intersegmental membranes. Tergite 2 predominantly shiny black, black extending ventrally to and just below auditory capsules; small central brown area within auditory capsule, and also submedially within black area of tergite; black colouration extending anteriorly from tergite 2 to tergite 1, filling area between timbals; tergites 3-8 and pygofer each with dorsal black areas that narrow posteriorly within each tergite and become progressively narrower from one tergite to the next, resulting in overall appearance of a strongly developed black fascia running dorsally along abdomen; tergites 3-6 each with small areas of black colouration ventro-laterally, largest and most intense on tergite 3, becoming smaller and weaker towards tergite 6; narrow, submedian red bands, each narrowing dorsally and ventrally, along posterior margins of tergites 3-7 of some specimens (notably those from 40km SSW Mt Surprise/Lynd Rd. Jct). Sternite II with median black area, otherwise sandy-brown; sternites III-VIII sandy-brown, slightly darker on sternite VIII.

Genitalia. (Fig. 4) Pygofer dominantly brown, black dorsally, including small dorsal beak. Upper pygofer lobes extended laterally with minor to no ventral curvature distally; apices of upper lobes relatively straight to very gently curved, posterodorsal 'corner' of apex relatively acutely rounded; aedeagus with long theca recurved into broad U-shape, apical ornamentation variable (notable in Slaty Creek specimens), with a thin, relatively narrow, lightly sclerotised, wafer-like process along inner curved theca margin, extending slightly beyond apex of theca, serrated distally; theca with ventral slit towards, and extending to apex, not always clearly visible; pseudoparameres absent.

FEMALE. (Pl. 1E) Very similar in colour and patterning to male, but with less black. Supra-antennal plate and vertex black, sandy-brown across entire anterior margin and extending to antennal pedicels. Postclypeus with broader sandy-brown margin that extends along transverse grooves and joins paler dorsal anterior margin of supra-antennal plate; mandibular plate and genae sandy-brown. Pronotum with central fascia broader and pale sandy-brown ventro-lateral colouration extending dorsally, thus reducing area of black colouration; scattered short golden pubescence. Mesonotum with submedian sigillae less extensively fused, and medial black fascia narrower and reaching, but not filling, area between anterior arms of cruciform elevation; lateral sigillae more irregular in outline and extensively broken by 'veinlets' of sandy-brown; rest of mesonotum, including cruciform elevation, sandy-brown. Fore coxae, trochanters, and femora dominantly sandy-brown, with erratic and incomplete darker brown fasciae on anterior faces; fore tibiae and tarsi, and mid and hind legs sandy-brown, apices of claws, and spines on fore femora, dark brown. Abdomen with dorsal black patches generally smaller; that on tergite 2 extending submedially; patches on 5-7 smaller and lighter, patch on tergite

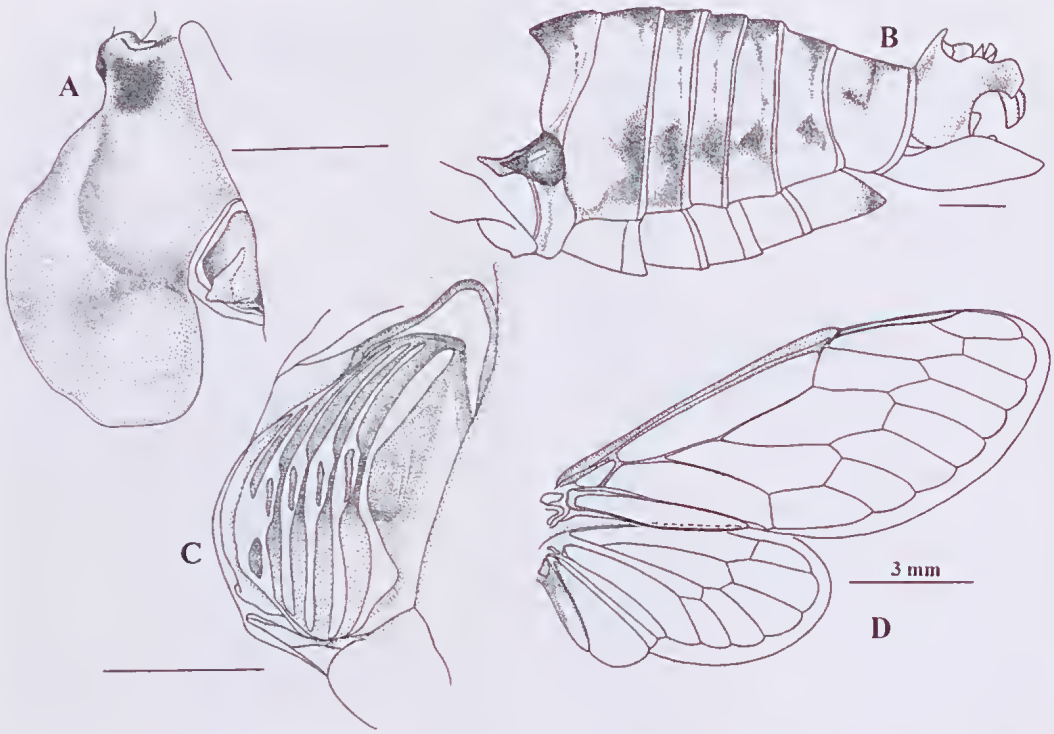

FIG. 6. *Graminitigrina karumbae* sp. nov. Karumba, SE Gulf of Carpentaria. A, left operculum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

8 very reduced and only small dark posterior spot on tergite 9; ventro-lateral dark markings absent on tergites 2-8; tergite 9 with pair of thin irregular pale brown submedial fasciae which merge posterodorsally, and a short, small brown ventro-lateral marking; tergites mostly sandy-brown with conspicuous reddish-brown submedial areas adjacent to posterior margins of each tergite, extending across intersegmental membranes. Sternites uniform sandy-brown. Ovipositor sheath extending ~0.5-1.0mm beyond apex of tergite 9.

MEASUREMENTS. *Bowen specimens*: N = 24♂, 2♀. Ranges and means (in parentheses): *BL*: ♂ 11.4-13.7 (12.4); ♀ 11.8-12.2 (12.0). *FWL*: ♂ 11.4-13.6 (12.7); ♀ 12.8 (12.8). *HW*: ♂ 3.0-3.5 (3.3); ♀ 3.3-3.4 (3.3). *PW*: ♂ 3.1-3.8 (3.5); ♀ 3.5-3.6 (3.5). *AW*: ♂ 3.6-4.1 (3.8); ♀ 3.4-3.6 (3.5). *FWL/BR*: ♂ 2.40-2.65 (2.53); ♀ 2.46-2.51 (2.49).

Croydon, Einasleigh River, and Lynd Highway specimens: N = 19♂, 6♀. BL: ♂ 11.2-13.2 (12.1); ♀ 10.7-13.3 (11.6). FWL: ♂ 11.8-14.0 (12.8); ♀ 12.0-14.3 (13.1). HW: ♂ 3.0-3.4 (3.1); ♀ 2.8-3.6 (3.2). PW: ♂ 2.9-3.6 (3.3); ♀ 3.0-3.8 (3.4). AW: ♂ 3.5-4.0 (3.8); ♀ 3.2-3.9 (3.5). FWL/BR: ♂ 2.43-2.66 (2.53); ♀ 2.46-2.58 (2.50).

Slaty Creek, Cloncurry specimens: N = 11♂, 13♀. BL: ♂ 14.0-14.7 (14.4); ♀ 12.8-14.5 (13.3). FWL: ♂13.5-16.2 (14.8); ♀ 13.0-15.7 (14.6). HW: ♂ 3.7-4.0 (3.8); ♀ 3.4-4.0 (3.8). PW: ♂ 3.4-3.7 (3.6); ♀ 3.1-3.7 (3.5). AW: ♂ 4.7-4.9 (4.8); ♀ 3.5-4.3 (4.1). FWL/BR: ♂ 2.44-2.64 (2.51); ♀ 2.44-2.50 (2.48).

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5). Known from seven localities, all in northern Queensland; Flagstaff Hill (Bowen); Croydon; Einasleigh River (~35km west of Mt Surprise); 40 and 49km SSW of Lynd-Mt Surprise road junction; 12km SE of the Lynd Road junction (39.5km NW of Greenvale) and Slaty Creek, SW of Cloncurry. The two most distant localities are separated by a linear distance of approximately 830km. Adults occurred in grassland with associated shrubs or low trees. In four localities, the substrate comprised siliceous metamorphic rocks and/or granites, or alluvium derived from these sources, the soils being shallow and poorly developed. The two localities 40 and 49km south of The Lynd-Mt Surprise road

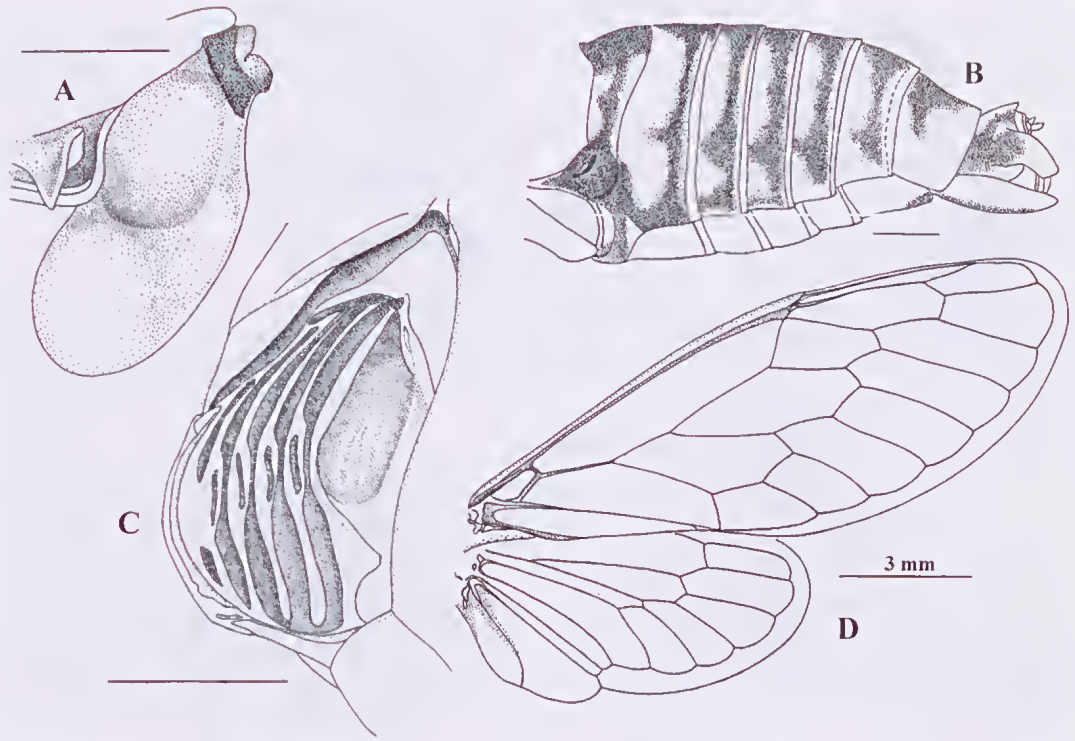

FIG. 7. *Graminitigrina karumbae* sp. nov. Heathlands, northern Cape York Peninsular. A, right opereulum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

junction lie on late Tertiary-Quaternary basalts, although south of the main basalt plateau, where the basalt sequences are topographically lower and approaching their outcrop limits. These cicadas have not been found on the main basalt plateau. They are elusive insects, very wary and fast flying when in singing mode, otherwise hiding cryptically in dense grass. The singing behaviour is described below in the song descriptions. Available records are for January-February.

ETYMOLOGY. From the type locality at Bowen, northeastern Queensland.

Graminitigrina karumbae sp. nov.
(Figs 5-8, 25-28, Plate 1F–H, Table 3)

TYPES. HOLOTYPE: ♂, QMT133333, 2km E. Karumba Pt. Village, Karumba, N.W.Q. AE 28 Jan 2002. 17°27.25'S 140°50.63'E, Photog. Spm PS1047 (QM).

PARATYPES. NORTH QUEENSLAND: 3♂, 4♀, 2km E. Karumba Pt. Village, Karumba, N.W.Q., Grass, AE, 28.i.2002, 17°27.25'S 140°50.63'E; 1♂, same data, Recorded Spec. 1; 1♂, same data, Recorded Spec. 2; 1♂, same data, Recorded Spec. 3; 1♂, same, Recorded Spec. 4; 1♂, 2km E. Karumba Point, N.Q., Grass, AE, 11.i.2003, 17°27.27'S 140°50.76'E, Recorded; 1♂, 2km E. Karumba Point, N.Q., Grass, AE, 12.i.2003, 17°27.27'S 140°50.76'E; 1♂, 1♀, 2km E. Karumba Point, N.Q., Grass, AE, 13.i.2003, 17°27.27'S 140°50.76'E; 1♂, 10.7km E. Heathlands, H.S. (Stn.), Cape York Peninsula, N.Q., 24.i.1992, Heath, AE, 11°45.22'S 142°39.54'; 2♂, same data, 25.i.1992 (AE). 1♂, 1♀, 2km E. Karumba Pt. Village, Karumba, N.W.Q., Grass, AE, 28.i.2002, 17°27.25'S 140°50.63'E (ANIC). 1♂, 2km E. Karumba Point. N.Q., Grass, AE, 11.i.2003, 17°27.27'S 140°50.76'E (BMNH). 1♂, Delta Downs Stn., E of Karumba, N.Q., on grass, 16.xii.1987, MSM and BJM (MSM).

DESCRIPTION. (Male). (A). *Karumba specimens* (Figs 6, 8A-B, Pl. 1G). *Head.* Supra-antennal plate, vertex, mandibular plate and genae black, covered by short golden and longer silver pubescence; small pale sandy-brown patches adjoining antennal pedicels; small pale sandy-brown triangular patch between ocelli extending to posterior margin of supra-antennal plate. Ocelli pink. Compound eyes dark brown. Postclypeus with pale sandy-brown margin and black transverse ridges; midline pale brown dorsally, grading to

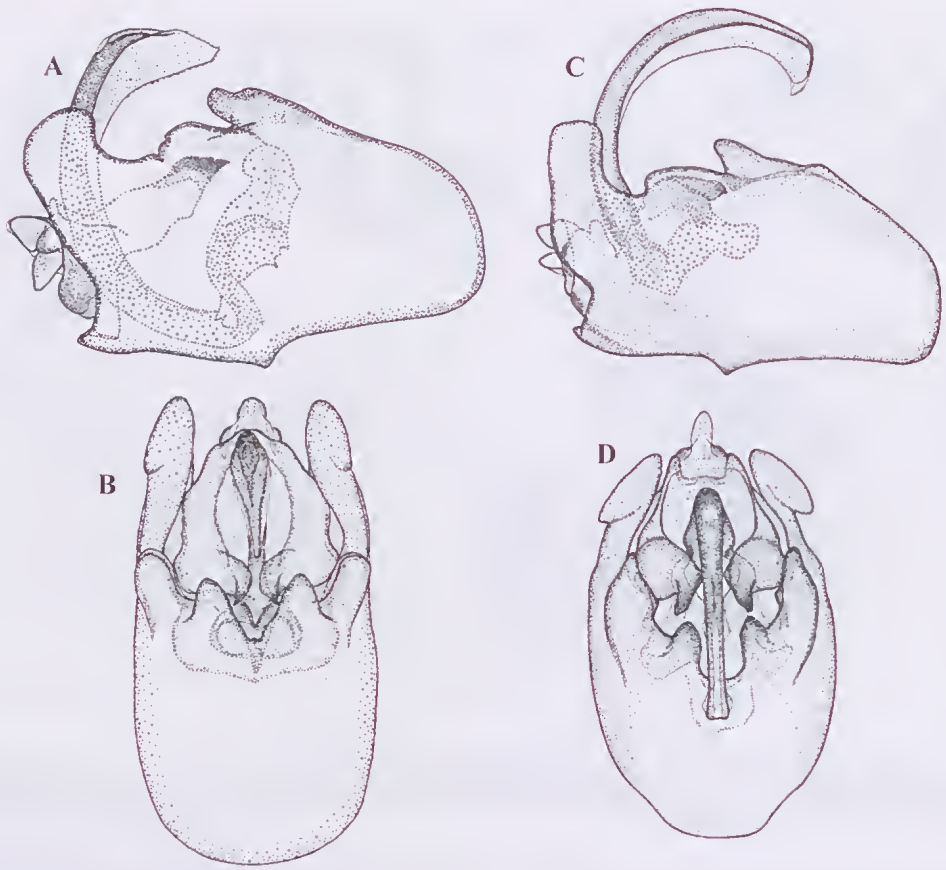

FIG. 8. *Graminitigrina karumbae* sp. nov. Pygofer and male genitalia, Lateral (top) and ventral views (bottom). Specimens from Karumba (A, B) and Heathlands (C, D). Length of pygofers, 2.75 and 2.3mm, respectively.

deep brown ventrally. Anteclypeus deep brown to black; rostrum brown grading to black apically. Antennae black, with brown pedicels.

Thorax. Pronotum mostly black with short, golden pubescence, anterior margin pale sandy-brown; pale sandy-brown central fascia extending from anterior pronotal margin to pronotal collar against which fascia flares out; pronotal collar pale sandy-brown, grading to black and markedly ampliate at lateral angles. Mesonotum with short black submedian sigillae completely fused medially, extending posteriorly as narrow black fascia, widening towards cruciform elevation, filling most of area between its anterior arms. Lateral sigillae black, posterior ends rounded and lying close to anterior arms of cruciform elevation; two small black patches between anterior and posterior arms of cruciform elevation; rest of mesonotum pale sandy-brown. Short sparse golden pubescence over most of mesonotum.

Wings. Venation pale sandy-brown, dark brown along anterior margin of costal vein. Hind wing with white, opaque plaga extending along margins of veins 3A and 2A.

Legs. Fore coxae mostly brown, with narrow, paler fasciae anteriorly; mid and hind coxae brown along lateral margins, otherwise pale sandy-brown. Trochanters and outer faces of fore femora pale sandy-brown, dark brown on posterior faces. Mid and hind femora pale sandy-brown with some darker brown longitudinal faseiae, less marked on hind femora. Tibiae and tarsi pale sandy-brown, claws slightly darker.

Opercula. Somewhat elongated, distal and medial margins broadly rounded, pale sandy coloured

except for small pale brown basal patches near crest in distolateral corners; meracantha spikes relatively short; medial area weakly slanted inwards towards abdominal midline; in lateral view, distal margin of opercula extending to anterior margin of sternite II; in ventral view, medial opercula margins markedly overlap distal margins of tympanal cavities.

Timbals. Long rib 4 fused dorsally to basal spur and ventrally to ribs 1-3; rib 5 close to, but not in contact with anterodorsal timbal margin, not extending more than half way along adjacent short rib; small, isolated long rib fragment located ventrally well below long rib 5; four clearly defined short ribs.

Abdomen. Maximum width across tergite 3 similar to that across auditory capsules; in dorsal view, abdomen narrowing gently to tergite 7, then tapering more strongly to pygofer. Tergites mostly sandy-brown; tergites 2-7 each with median, brown to black, roughly triangular-shaped patch that is widest posteriorly; patch on tergite 2 confluent with central dark patch on T1 that fills area between timbals; central patches becoming paler brown towards tergite 7; tergite 8 with two dark, irregular patches joined by a thin, transverse dark line. Tergites 2-6 laterally with smaller, roughly triangular-shaped brown patches that are widest posteriorly. Sternites sandy-brown, VII and VIII slightly darker.

Genitalia. (Fig.8) Pygofer sandy-brown with two somewhat irregular, thin, submedian, brown fasciae tending to converge posteriorly. Upper pygofer lobes strongly decurved; apices broadly rounded; aedeagus with long theca recurved into broad U-shape; thin, lightly sclerotised, finely serrated, wafer-like process along inner curve of theca, widening and extending beyond tip of theca apically; theca with distinct ventral split towards, and extending to apex; pseudoparameres absent.

(B). Heathlands specimens. (Figs 7, 8, Pl. 1F) Head and thorax very similar to Karumba specimens but pale central fascia on pronotum not quite extending to pronotal collar, pale pronotal collar wider submedially. Principally differ from Karumba specimens in increased extent and intensity of black colouration on abdomen. Dorsal black markings wider than Karumba specimens, extending from between timbals on tergite 1 to pygofer, together

TABLE 3. *Graminitigrina karumbae* - summary of calling song parameters. Data compiled from separate container recordings from three insects (Karumba Point) and one insect (Heathlands).

Location	Karumba Point	Heathlands, Cape York
a. Chirp phrases (=short echemes ± associated clicks)		
Repetition rates (s^{-1})	0.51(0.66-0.33)[1]	0.47(0.65-0.33)
No. of initial clicks per chirp phrase	6.9(2-13)[1]	4.6(3-9)
Total chirp lengths (s)	1.05(0.85-1.22)[1]	1.27(1.06-1.45)
b. Single click phases (= single discrete macrosyllables)		
Macrosyllable lengths (ms); excluding tails	13.4(11.5-14.2)[1]	20.6(18.0-21.7)
Macrosyllable lengths (ms); including tails	16.8(15.0-17.7)[1]	24.7(22.7-26.5)
Syllable lengths (ms); excluding tails	2.6(2.3-2.9)[1]	3.4(3.2-3.9)
Syllable lengths (ms); including tails	7.6(6.6-9.0)[1]	12.5(11.5-13.0)
Hemisyllable lengths (ms)	0.73(0.54-0.88)[1]	0.76(0.44-1.02)
Click repetition rates (s^{-1})	2 - 68	3 - >100
Doublet intervals; main sequence prior to echeme (ms)	9.0(0.83-10.2)[1]	12.5(11.4-13.3)
Doublet intervals; final 3 to 6 clicks adjacent to echeme (ms)	4.5-7.7	4.5-7.4 (final 3)
Secondary peak widths (ms)	2.3(2.0-2.8)[1]	2.4(2.2-2.5)
c. Short echeme phrases		
Macrosyllable lengths (ms)	11.5(10.9-13.3)[1]	15.2(14.3-15.6)
Syllable lengths (ms)	1.5(1.3-2.0)[1]	2.4(1.3-2.9)
Syllables per macrosyllable	7	7
Hemisyllable lengths (ms)	0.62(0.41-0.92)[1]	0.50(0.38-0.70)
d. Dominant frequency (kHz)	8.88 (8.50-9.12)[1]	7.85

[1]Values represent mean and (ranges).

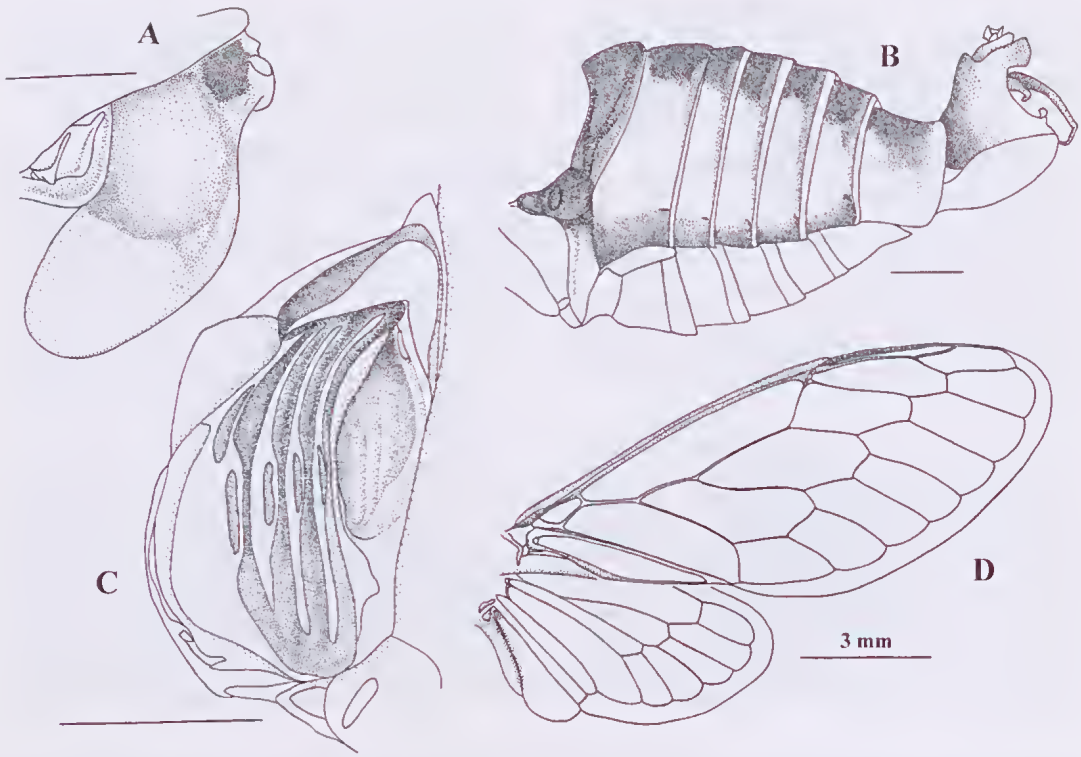

FIG. 9. *Graminitigrina bolloni* sp. nov. A, right opereulum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Seale bars 1mm, exeept wings (3mm).

creating appearance of dark, dorsal faseia. Tergite 2 with narrow irregular transverse band extending laterally to, and enelosing auditory eapsule; tergites 3-7 with posterior, narrow, dark transverse bands that are conspieuously widened ventrally; bands on tergites 3 and 4 extending to ventral margins of tergites in lateral view; rest of tergites sandy-orange-brown, more intense than in Karumba speeimens. Sternite II exhibits a narrow brown zone, parallel to submedian margin; sternites III-VII sandy/orange-brown, tergite VII dark posteriorly; sternite VIII sandy-orange-brown laterally, dark brown medially. Legs similar to Karumba speeimens in general patterning but dark areas more extensive and darker. Timbal structure very similar, but long rib 4 not fused either dorsally to basal spur, or ventrally to ribs 1-3. Some minor differences in shape of pygofer, the lower lobe, and detailed shape of wafer-like process extending along inner margin of theca.

FEMALE. (Pl. 1H) *Karumba locality.* Similar to male but slightly paler overall. Supra-antennal plate and vertex black to deep brown, with pale sandy-brown area along anterior margin extending from frontoclypeal suture almost to compound eyes; pale fascia extending from median ocellus to posterior margin of supra-antennal plate. Postelypeus as in male, but deep brown rather than black; anteclypeus brown to sandy-brown; rostrum sandy-brown grading to black apically. Pronotum mostly black to dark brown; central fascia pale sandy-brown with thin brown edges; pronotal collar as in male. Mesonotum as in male with submedian and lateral sigillae slightly smaller. Wings and legs similar to male. Abdominal markings similar in form and shape to male, but generally slightly paler; dorsal brown markings on tergites 2-7; tergites 8 and 9 predominantly pale sandy-brown. Sternites uniformly pale sandy-brown. Ovipositor sheath extending 0.5-1mm beyond apex of tergite 9.

MEASUREMENTS. N = 15♂, 5♀. Ranges and means (in parentheses). *BL*: ♂ 12.2-13.5 (13.0); ♀ 11.0-11.2 (11.1). *FWL*: ♂ 12.2-14.0 (13.0); ♀ 12.6-13.0 (12.8). *HW*: ♂ 3.0-3.4 (3.2); ♀ 3.0-3.2 (3.1). *PW*: ♂ 3.3-3.9 (3.5); ♀ 3.3-3.5 (3.4). *AW*: ♂ 3.8-4.1 (3.9); ♀ 3.5-

3.6 (3.5). *FWL/BR*: ♂ 2.42-2.62 (2.54); ♀ 2.52-2.68 (2.60).

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5). Known from three localities in northern Queensland; Karumba Point (southeastern Gulf of Carpentaria), Delta Downs NE of Karumba and Heathlands, northern Cape York Peninsula, the two most distant localities separated by a linear distance of 655km. At Karumba Point, adults occur in grassland on low plains, formed of coastal alluvial deposits, seasonally inundated by freshwater. At Heathlands, the cicada occur in dense low heathland, dominated by *Sinoga lysicephala*, lying on weathered quartzose sandstones and siltstones of Mid Jurassic-Early Cretaceous age (Helby Beds). The adults of this species are highly elusive, being very wary and fast flying when disturbed, often flying up to 10m, but sitting cryptically when not singing. The singing behaviour is described below. Records are available only for December and January, following monsoonal rains.

ETYMOLOGY. From the type locality at Karumba Point, southeastern Gulf of Carpentaria, north Queensland.

Graminitigrina bolloni sp. nov.
(Figs 5, 9,10, 29 - 32, Plate 2A–B, Table 4)

MATERIAL. HOLOTYPE: ♂, QMT133334, 0.7km E. Bollon, S.Q. Grass. 12 Dec. 2001, AE 28°01.85'S 147°29.39'E: Photog. Spm PS1046. PARATYPES: SOUTHERN QUEENSLAND: 1♂, 0.7km E. Bollon, Grass, 10.xii, 2001, AE, 28°01.85'S 147°29.39'E; 1♂, same data, Recorded Spec. 1; 1♂, same data, Recorded Spec. 2; 1♂, same data, Recorded Spec. 3; 1♂, 1♀, same data but 12.xii, 2001; 4♂, 1♀, 1 exuvia, 1km S.E Bollon, S.Q., 20.xii.2004, Grass (in mulga), AE, 28°02.27'S 147°29.49'E; 1♂, same data, Recorded 1; 1♂, same data, Recorded 2; (AE). 1♂, QLD 27°32'01"S 148°50'25"E, 65km NNE. St George, 9.i.2005. Roadside. L.W. Popple, R. MacSloy, 370-0001*; 7♂, 10km E. of Jericho, 11.i.2007,Grassland, L. Popple, J. Herewood, 23°36'37"S 146°14'34"E, 371-0007* (LWP). 1♂, 1♀, 1km S.E Bollon, S.Q., 20.xii.2004, Grass (in mulga). AE, 28°02.27'S 147°29.49'E; (ANIC). 1♂, same data (BMNH). 1♂, same data (MSM).

*Species and specimen numbers in private collection of LWP.

DESCRIPTION. (Male). Figs 9, 10, Pl 2A. *Head.* Supra-antennal plate, vertex, mandibular plate and genae shiny black, covered by short golden pubescence (supra-antennal plate only), and longer silvery pubescence; small sandy-brown patches extending along anterior margin of supra-antennal plate from pedicels of antennae to lateral margin of

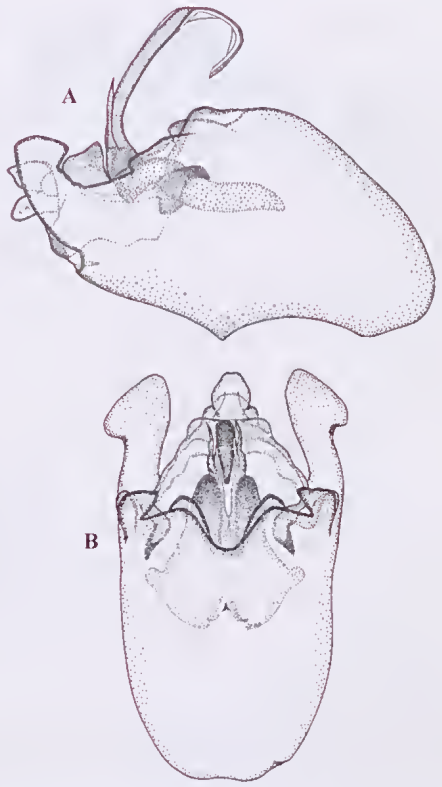

FIG. 10. *Graminitigrina bolloni* sp. nov. Pygofer and male genitalia, lateral (A) and ventral views (B). Specimen from Bollon. Length of pygofer, 2.6mm.

postclypeus; short triangular sandy-brown fascia extending from median ocellus, and widening towards and reaching posterior margin of vertex. Ocelli pink to rose-red. Compound eyes deep brown. Dorsal surface of postclypeus shiny black with short golden pubescence dorsally; anterior surface shiny black with narrow pale chestnut brown margin which does not extend along transverse grooves; small sandy-brown dorsal spot on midline. Anteclypeus shiny black; rostrum pale brown, grading to black apically. Antennae mostly black with pale brown pedicels.

Thorax. Pronotum shiny black, ventro-lateral margins sandy-brown; sandy-brown central fascia extending from anterior margin towards, but not quite reaching posterior margin; pronotal collar pale chestnut brown with a broader sandy-brown margin submedially; lateral angles of pronotal collar markedly ampliate and pale chestnut brown; pronotum covered with short golden pubescence. Mesonotum with submedian sigillae black, short, completely fused medially; very narrow black

TABLE 4. *Graminitigrina bolloni* - summary of calling song parameters. Data compiled from separate recordings from four insects (Bollon; container recordings) and two insects (Jericho; field recordings).

	Bollon ('normal' song)	Jericho
Chirps (short echemes + associated clicks)		
1. Chirp repetition rates $^{(s-1)}$		
(a) Echeme + 2 clicks	2.2(3.3-1.9)	-
(b) Echeme + 3 clicks	2.4(2.3-2.9)	4.2(3.7-4.5)
(c) Echeme + 4 clicks	1.9(2.1-1.8)	4.4(3.7-5.0)
2. Short echeme lengths (ms)	64(54-90)	46(39-60)
3. Inter-click intervals and repetition rates (ms)		
(a) Excluding final 3 clicks (1 to 3) (only for ≥4 click sequences):	157(124-191) [6.4Hz(8.1-5.2Hz)]	39(34-42) [26Hz(29-24Hz)]
(b) Between clicks 3 to 2	104(86-113) [9.6Hz(11.6-8.9Hz)]	41(36-47) [24Hz(28-21Hz)]
(c) Between clicks 2 to 1	53(43-67) [19Hz(23-15Hz)]	29(27-32) [34Hz(37-31Hz)]
(d) Between click 1 and echeme	29(23-38) [34Hz(43-26Hz)]	22(18-24) [45Hz(23-42Hz)]
4. Individual clicks (= single macrosyllables)		
A. Triplet click sequences (including initial syllable of each click)		
(i) Total click length (excluding final tail)(ms) [=Macrosyllable]	21.7(19.9-23.7)	14.0(13.0)-16.2)
(a) Inter-syllable intervals (ms) - see Fig. 31c		
(i) Syllables 1 to 2 intervals	8.0(6.8-9.1)	4.2(3.9-5.0)
(ii) Syllables 2 to 3 intervals	7.8(5.3-8.7)	9.4(9.0-9.7)
B. Quadruplet click sequences (including initial syllable of each click)		
(i) Total click length (excluding final tail)(ms) [=Macrosyllable]	30.6(26.1-33.0)	13.3(12.5-14.1)
(b) Inter-syllable intervals (ms) - see Fig. 31b		
(i) Syllables 1 to 2	8.4(7.3-9.2)	3.7(3.5-4.3)
(ii) Syllables 2 to 3	9.3(8.1-9.5)	5.5(5.1-7.0)
(iii) Syllables 3 to 4	10.0(9.9-10.2)	3.2(2.0-4.2)
C. Syllable lengths (ms) - all data		
(i) Syllable 1	4.4(3.6-5.3)	1.2(0.8-1.9)
(ii) Syllable 2	6.0(4.6-7.9)	2.4(2.0-3.3)
(iii) Syllable 3	5.6(4.4-7.9)	2.0(1.9-2.1)
(iv) Syllable 4	4.4(4.0-4.8)	1.6(1.3-2.3)
D. Occurrence of triplet/quadruplet click sequences		
(i) Triplet sequences	>3 clicks per echeme	-
(ii) Quadruplet sequences	≤3 clicks per echeme	-
E. Hemisyllable lengths (ms) - 4 per syllable		
(i) Syllable 1	0.91(0.53-1.2)	-
(ii) Syllable 2	1.2(0.56-1.7)	-
(iii) Syllable 3	0.89(0.40-1.13)	-
(iv) Syllable 4	1.1(0.81-1.8)	-
5. Echemes (multiple coalesced macrosyllables)		
A. Macrosyllables - lengths (ms)	16.0(12.0-20.9)	9.0(8.6-13.7)
B. Syllable lengths (ms)	3.8(2.4-6.0)	2.5(1.8-5.1)
6. Dominant frequency (kHz)	9.63 (9.30-10.22)	9.28 (9.03-9.53)

Figures are means and (ranges); figures in square brackets are equivalent frequencies (Hz).

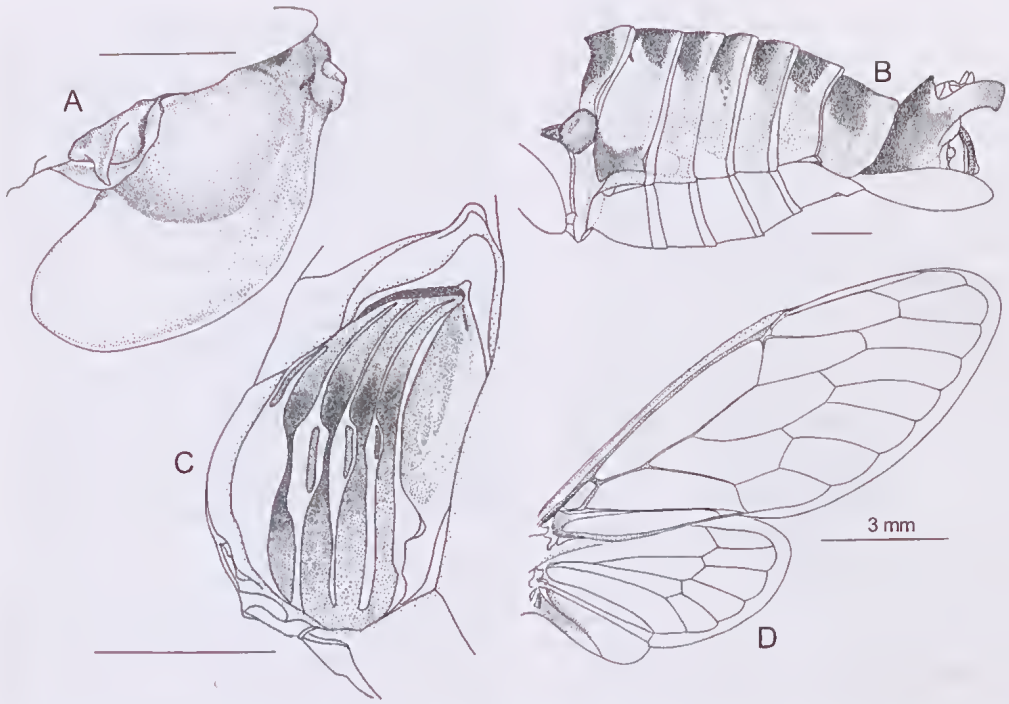

FIG. 11. *Graminitigrina carnarvonensis* sp. nov. Mt Moffatt Section of Carnarvon National Park. A, right operculum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

fascia extending posteriorly from submedian sigillae, widening abruptly near, and extending between anterior arms of cruciform elevation; lateral sigillae black, roughly triangular, narrowing posteriorly, terminating near apices of anterior arms of cruciform elevation; medial edges of sigillae broken by 'veinlets' of sandy-brown colouration; small, irregular, dark brown patches within areas between anterior and posterior arms and between both posterior arms of cruciform elevation; rest of mesonotum, including wing grooves, sandy-brown; mesonotum with sparse silvery pubescence, longer and more profuse around cruciform elevation.

Wings. Venation pale sandy coloured, becoming brown apically; costal vein very pale sandy-yellow; very narrow sclerotised brown anterior margin to costal vein. Hind wing with white opaque plaga along margins of veins 3A and 2A, and weak brown infuscation centrally within anal cell 3; four to five apical cells.

Legs. Fore coxae sandy-brown with lozenge-shaped dark brown areas covering much of anterior faces, posterior faces with broad short dark brown fascia; mid and hind coxae similar but with smaller paler brown markings; trochanters and fore femora mostly dark brown on anterior faces, sandy-brown with two broad longitudinal fasciae on posterior faces; mid femora sandy-brown with a pair of brown fasciae on posterior faces; hind femora similar, with fasciae thinner and paler; fore tibiae and tarsi medium to dark brown; mid and hind tibiae and tarsi sandy-brown; claws sandy-brown with dark brown apices.

Opercula. Relatively elongated and narrowly rounded along distal-medial margins; distal area gently curved towards abdominal midline; sandy coloured except for small dark brown patches near basal crests; basal half of operculum convex, broad and dome-like; spikes on meracantha short, broad, not overlapping opercula plates; in lateral view, operculum just overlapping anterior margin of sternite II submedially.

Timbals. Long ribs 1-4 fused ventrally, and dorsally to basal spur; rib 5 short, not reaching anteriormost short rib; 4 clearly defined short ribs; dome on timbal plate with distinct ridges, approximately parallel to long ribs.

Abdomen. Maximum width across tergite 3 slightly greater than across auditory capsules; in dorsal view, abdomen evenly tapering from tergites 3-8. Tergite 2 shiny black except for narrow, pale sandy-brown posterior margin, black colouration extending across, and just beyond ventral margins of auditory capsules, and anteriorly to between timbals on tergite 1; tergites 3-8 with well defined, shiny black, dorsal patches, more or less subequal in width on tergites 3-7; within each tergite, patches taper posteriorly, those on tergites 4-7 not extending on to, or across intersegmental membranes; dark dorsal patch on tergite 9 larger, extending to about lateral margin of tergite in dorsal view; tergites 3-7 with black to dark brown patches along ventrolateral margins, these becoming smaller and paler posteriorly; remaining colouration of tergites pale sandy-brown to dark sandy-brown, progressively darkening distally; posterior margins of tergites 3-6 with distinct reddish-chestnut brown zones submedially, these not extending across intersegmental membranes; dorsally, these reddish-brown zones lie between black dorsal patches and intersegmental membranes. Sternite II pale sandy-brown, black medially ; sternites III-VI sandy-brown, VII-VIII slightly darker.

Genitalia. (Fig. 10) Pygofer dark brown dorsally and basally and on upper lobes, otherwise sandy-brown. Upper pygofer lobes relatively sharply decurved; apices with acutely rounded corners, distal margin straight to gently convex; aedeagus with long, strongly curved theca, its apex recurved 180° and hook-like; pseudoparameres distinct, much shorter than theca, originating near thecal base.

FEMALE. (Pl. 2B) Very similar in overall colouration to male, but with slightly more extensive pale areas. Differing from male as follows: larger sandy-brown patches around pedicels of antennae and along margins of genae. Postclypeus with broader sandy-brown margin and enlarged sandy-brown spot dorsally on midline of frons. Antennae dark brown, pedicels sandy-brown. Mesonotum similar to male, except median, narrow, black fascia extending from nearly coalesced black submedian sigillae only extending midway along mesonotum, not reaching anterior arms of cruciform elevation; two small black spots (scutal depressions) distinct, not enveloped within dark colouration; central area of cruciform elevation reddish. Wings as in male, one specimen examined with only 3 hind wing apical cells. Legs; fore coxae mostly sandy-brown with faint, pale brown, broad fascia; mid and hind coxae with reduced brown markings; femora and trochanters with narrower and paler brown fasciae; tibiae and tarsi sandy-brown, with claws darker brown on apices. Abdomen: tergite 2 black dorsally and submedially along anterior margin, dorsal black marking reducing in width towards posterior margin and not extending over intersegmental membrane; tergite 2 otherwise sandy-brown with narrow chestnut-brown submedian area adjacent to posterior margin; tergites 3-8 with dorsal, well-defined, black patches that decrease in width posteriorly within each tergite; patches progressively decreasing in size from tergites 3-8; tergites 3-8 each with narrow but distinct reddish to chestnut-brown zone dorsally and submedially along posterior margins; tergites otherwise pale to medium sandy-brown, darkening posteriorly towards tergite 8; tergite 9 sandy-brown with a pair of brown, submedian, longitudinal fasciae, that terminate approximately three-quarters along length of tergite; each fascia slightly expanded and rounded posteriorly; less conspicuous, paler brown dorsal fascia of tergite 9, narrowing posteriorly and shorter than paramedial fasciae; sternites pale sandy-brown. Ovipositor sheath extending 0.8-1.1mm beyond apex of tergite 9.

MEASUREMENTS. N = 16♂, 2♀. Ranges and means (in parentheses). *BL*: ♂ 10.7-12.3 (11.6); ♀ 11.2-12.7 (12.0). *FWL*: ♂ 12.0-12.5 (12.3); ♀ 12.4-12.7 (12.6). *HW*: ♂ 3.0-3.3 (3.1); ♀ 3.2 (3.2). *PW*: ♂ 3.1-3.6 (3.4); ♀ 3.5-3.6 (3.5). *AW*: ♂ 3.4-3.9 (3.7); ♀ 3.3-3.6 (3.5). *FWL/BR*: ♂ 2.34-2.58 (2.46); ♀ 2.44-2.48 (2.45).

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5) Known from three localities in southern to central inland Queensland; Bollon, 65km NNE of St George and 10km E of Jericho, a distribution extending over a linear distance of approximately 505km. At each location, the cicada occurs only in grassland: at Bollon within open mulga (*Acacia aneura*) woodland; north of St George within poplar box (*Eucalyptus populnea*)-*Eremophila mitchellii-Callitris*-sparse mulga open woodland; at Jericho, within mixed eucalypt-acacia (e.g. *E. melanophloia, E. crebra, E. cambageana, A. melvillei, A. shirleyi*) open woodland with *Kunzia* sp. At Bollon, the bedrocks are quartz sands, silts and gravels, giving rise to sandy or loamy soils. The locality north of St George is also dominated by lithic sandstones, siltstones and minor mudstones, and alluvium derived from these, with soils that are gravelly and loamy red earths. The Jericho locality

is likewise characterised by quartz sandstones and siltstones and their derived gravelly soils.

The adults of this species are highly elusive and fast flying insects while singing. In between bouts of song, they rest very cryptically, low on dense grass stems. The singing behaviour is described in more detail below. The insect emerges after heavy summer rains. Available records are for December to January.

ETYMOLOGY. From the type locality Bollon, southern Queensland.

Graminitigrina carnarvonensis sp. nov.
(Figs 5, 11, 12, 33-35, Plate 2C–D, Table 5)

MATERIAL. HOLOTYPE: ♂, QMT133335, 24°59'28"S 147°53'48"E Mt Moffatt NP, SCQ, Marlong Arch. 820m, 19 Nov 1995, C.J. Burwell, Photog. Spm PS1044.

PARATYPES: SOUTH QUEENSLAND: 1♂, 4.3km NNE., Mt Moffatt NP entrance gate, grass,13.xii.2006, AE, 25°05.09'S 147°52.42'E; 1♂, 6.9km SW., triple Jct of tracks Inform. Ctre-Marlong-Top Shelter, Mt Moffatt., grass, 14.xii.2006,AE, 24°58.52'S 147°55.92'E; 4♂, 3.7km NE. Marlong Arch, along rd, Mt Moffatt NP, grass, AE, 15.xii.2006, 24°58.44'S 147°56.17'E; 1♂, same data, Field recorded, open net; 1♂, 4.3km NNE., Park Entrance, Mt Moffatt N.P., grass, AE, 16.xii.2006, 25°05.06'S 147°52.49'E (AE). 3♂, 25°01'S 147°47'E, Mt Moffatt NP, Park Headquarters, 17.xi.1995, 740m CJB; 1♂, 25°04'39"S 148°00'30"E Mt Moffatt NP, Base of the Tombs, 17.xi.1995, 700 m, S. Gaimari; 1♀ 25°01'S 147°47'E, Mt Moffatt Nat. Pk. Park Headquarters, 18.xi.1995, 740m CJB; 1♂, 25°05'S 147°53'E, Base of the Tombs, Mt Moffatt Nat. Pk., 28.xi-3.xii.1997, Evans, Skevington, Lambkin (QM). 1♂, Queensland Camarvon NP, Mt Moffatt, 25° 06'00"S 147°51'15"E, C. Eddie, 29:xi:1995, 371-0006*; 3♂, QLD 24°57'25"S 147°54'19"E, Mt Moffatt NP, North-west Rd., 15.i.2005, L.W. Popple, 371-0005,4,3*; 2♂, QLD, 25°05'21"S 147°52'23"E, The Tombs, Mt Moffatt NP, 14.i.2005, L.W. Popple, 371-0002* (LWP). 1♂, Qld: Camarvon NP, Mount Moffatt Section, Malaise, 25°03'15'S 147°53'12"E, 26.xi.1997, J. Skevington, C. Lambkin; 1♂, same data, 1-2.xii.1997; 1♂, QLD: Camarvon NP; Mt Moffatt Section, Mt Moffatt Rd, Sandy Creek, 25°04'01'S 148°00'50"E, 2.xii.1997, J. Skevington, C. Lambkin, S. Evans, malaise (JM). 1♂, 25°04'39"S 148°00'30'E, Mt Moffatt Nat. Pk, 3km SE Park Headquarters, 20.xi.1995, 740m, CJB; (ANIC). 1♂, 25°02'18'S 147°58'30"E, Mt Moffatt NP, 3km SE Park Headquarters, 19.xi.1995, 740m, Irwin, Gaimari, Yeates, Burwell, Malaise (BMNH). 1♂, Chesterton Range N. P., Qld, 10.xii.1995, spinifex, eucalypt open woodland, Colin Dollery (MSM).

*Species and specimen numbers in private collection of LWP.

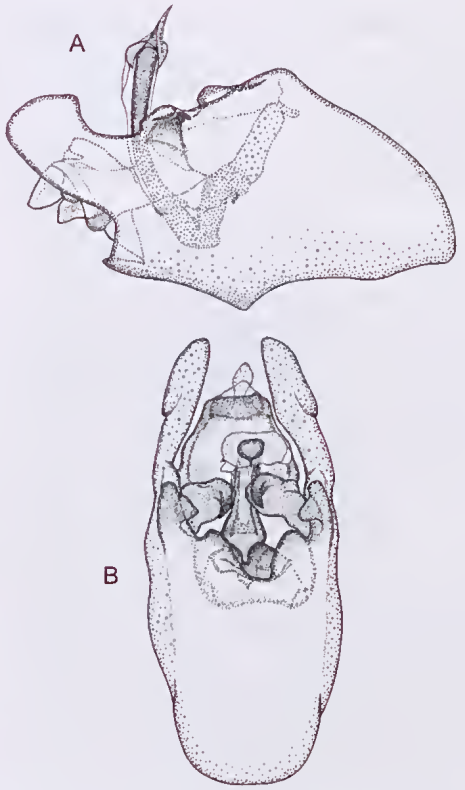

FIG. 12. *Graminitigrina carnarvonensis* sp. nov. Pygofer and male genitalia, Lateral (A) and ventral views (B). Specimen from Mt Moffat. Length of pygofer, 2.9mm.

DESCRIPTION. (Male). Figs 11, 12, Pl. 2C. *Head.* Supra-antennal plate and vertex shiny black, with narrow anterior sandy-brown rim extending around pedicels of antennae, but not to margins of compound eyes; short, triangular, pale sandy-brown fascia extending from near median ocellus, widening towards, and reaching posterior margin of vertex; sparse dorsal short golden pubescence; mandibular plate shiny black, genae black dorsally, pale reddish brown along lateral to ventral margins; long yellowish pubescence on mandibular plate and genae. Ocelli rose-red. Compound eyes chestnut-brown. Postclypeus shiny black, covered with short golden pubescence on dorsal surface; anterior surface shiny black with pale chestnut-brown margin which only slightly extends along transverse grooves; small pale sandy-brown spot middorsally. Anteclypeus shiny black; rostrum pale

TABLE 5. *Graminitigrina carnarvonensis* - summary of calling song parameters. Data compiled from separate open net field recordings from three insects (Mt Moffatt).

1. Chirp phrases		
(i) Chirp lengths (ms)		151(120-190)[1]
(ii) Chirp repetition rates (ms)		261(209-366)[3.8Hz(4.8-2.7Hz)][2]
2. Click phases (= diplosyllables)		
(i) *Inter-hemisyllable intervals (ms)*		
Diplosyllable 1	- initial to second hemisyllable	20.3(17.9-21.7)[49Hz][3]
	- second hemisyllable to following diplosyllable	44.5(32.7-59.8)[22Hz]
Diplosyllable 2	- initial to second hemisyllable	17.8(14.8-20.7)[56Hz]
	- second hemisyllable to following diplosyllable	20.6(15.1-29.6)[49Hz]
Diplosyllable 3	- initial to second hemisyllable	8.3(4.8-10.0)[120Hz]
	- second hemisyllable to following diplosyllable	13.3(11.1-15.8)[75Hz]
Diplosyllable 4	- initial to second hemisyllable	5.2(3.7-5.9)[192Hz]
	- second hemisyllable to following diplosyllable	9.7(8.2-13.6)[103Hz]
Diplosyllable 5	- initial to second hemisyllable	5.0(4.9-5.6)[200Hz]
	- second hemisyllable to following diplosyllable	7.2(5.8-9.9)[139Hz]
Diplosyllable 6	- initial to second hemisyllable	5.0(3.5-5.6)[200Hz]
(ii) *Inter-diplosyllable intervals (ms)*		
Diplosyllables	1 to 2	64.9(51.9-81.5)[15Hz]
	2 to 3	38.3(31.1-45.2)[26Hz]
	3 to 4	21.6(18.3-25.4)[46Hz]
	4 to 5	13.9(13.4-17.3)[72Hz]
	5 to 6	12.1(10.5-13.4)[83Hz]
(iii) *Hemisyllable doublet intervals between peak pairs (ms)*; S = single initial hemisyllables		
Diplosyllable 1	- initial (dominant) hemisyllable	S
	- second hemisyllable	1.6(0.9-2.0)[625Hz]
Diplosyllable 2	- initial (dominant) hemisyllable	S→1.2
	- second hemisyllable	1.7(1.4-2.0)[588Hz]
Diplosyllable 3	- initial (dominant) hemisyllable	S→2.3
	- second hemisyllable	2.1(1.4-2.7)[476Hz]
Diplosyllable 4	- initial (dominant) hemisyllable	1.4(0.6-2.1)[714Hz]
	- second hemisyllable	1.5(1.0-1.8)[667Hz]
Diplosyllable 5	- initial (dominant) hemisyllable	1.5(0.4-2.1)[667Hz]
	- second hemisyllable	1.4(1.1-2.0)[714Hz]
Diplosyllable 6	- initial (dominant) hemisyllable	1.7(0.9-2.6)[588Hz]
	- second hemisyllable	1.5(0.8-2.0)[667Hz]
(iv) *Hemisyllable lengths (ms)*; S = single initial hemisyllables		
Diplosyllable 1	- initial (dominant) hemisyllable	1.7-1.9; S.
	- second hemisyllable	2.2-2.4
Diplosyllable 2	- initial (dominant) hemisyllable	1.7-2.0; S→Doublet
	- second hemisyllable	2.4-3.0
Diplosyllable 3	- initial (dominant) hemisyllable	2.0-2.8; S→Doublet
	- second hemisyllable	2.4-3.0
Diplosyllable 4	- initial (dominant) hemisyllable	2.9-3.3
	- second hemisyllable	2.1-2.3
Diplosyllable 5	- initial (dominant) hemisyllable	2.6-2.8
	- second hemisyllable	2.1-2.2
Diplosyllable 6	- initial (dominant) hemisyllable	2.7-2.8
	- second hemisyllable	2.0-2.2
(v) *Small 'pulse disturbances' following initial hemisyllable; intervals between 'disturbance' and initial hemisyllable*, and 'disturbance' length (in brackets); (ms).		
Diplosyllable 1	initial hemisyllable to 'disturbance'	2.5-5.6(1.1-1.9)
Diplosyllable 2	initial hemisyllable to first 'disturbance'	3.2-5.4(0.1-1.0)
Diplosyllable 3	initial hemisyllable to 'disturbance'	3.2-5.4(0.9-1.0)
3. Dominant frequency (kHz)		10.11 (9.78-10.60)

[1]Values represent mean and (ranges). [2]Values represent mean, (ranges) and [equivalent mean and ranges of frequency]. [3]Equivalent mean frequency of mean inter-diplosyllable intervals.

sandy-brown, grading to black apically. Antennae deep brown with pale sandy-brown pedicels.

Thorax. Pronotum shiny black, ventro-lateral and narrow anterior margins pale sandy-brown; pale sandy-brown central fascia extending from anterior margin to, and splaying out along anterior margin of pronotal collar; pronotal collar black with narrow, pale sandy to chestnut-brown posterior margin; lateral angles of pronotal collar

markedly ampliate; pronotum with sparse, short, silver-yellow pubescence. Mesonotum mostly black due to complete fusion of submedial sigillae which extend posteriorly, with initial slight medial narrowing and then widening, to completely cover area between anterior arms of cruciform elevation; broad black lateral sigillae extending from anterior mesonotal magin, with some narrowing, to just beyond apices of anterior arms of cruciform elevation; lateral mesonotal margins, very narrow zones between lateral and submedial sigillae, wing grooves, and cruciform elevation pale sandy-brown; small darker areas between anterior and posterior arms of cruciform elevation, and within posterior area of wing grooves.

Wings. Fore wing venation pale sandy-brown, becoming brown apically; costal vein pale sandy to medium brown in mid part of vein; very narrow sclerotised brown anterior margin to costal vein; apex of fore wing with diffuse, weak brown infuscation, extending from approximately apical cell 4. Hind wing with white opaque plaga extending along margin of veins 3A and weakly along vein 2A, with pale brown infuscation centrally in anal cell 3; four to five apical cells.

Legs. Fore coxae with broad and somewhat irregular dark brown fasciae covering much of anterior and lateral faces, otherwise pale sandy-brown; mid coxae pale sandy-brown, lateral faces mostly deep brown; hind coxae pale sandy-brown; fore trochanters and femora with broad, dark brown fasciae on anterior and posterior faces, otherwise pale sandy-brown; mid and hind trochanters pale sandy-brown; mid femora pale sandy-brown with irregular brown fasciae on anterior faces; hind femora mostly pale sandy-brown with pair of weakly developed, pale brown fasciae along posterior faces; fore tibiae and tarsi mainly dark brown; mid and hind tibiae and tarsi pale sandy-brown with scattered small brown irregular patches; claws sandy-brown to brown, darkest apically.

Opercula. Relatively elongated, distal and medial margins broadly rounded and gently inclined towards abdominal midline; pale sandy coloured with two small, weak pale brown markings near basal crests; basal half of opercula convex, broadly dome-like; spikes on meracantha narrow and sharply pointed, only slightly overlapping opercula plate; operculum not quite reaching anterior margin of sternite II in lateral view.

Timbals. Long ribs 1-3 fused ventrally, and dorsally to basal spur; long rib 4 fused dorsally to basal spur; long rib 5 not extending across timbal plate to narrowed mid region of long rib 4; no anterior short rib, 3 short ribs only; elongated, narrow dome on timbal plate with distinct ridges, approximately parallel to long ribs.

Abdomen. Maximum width across tergite 3 slightly greater than across auditory capsules; in dorsal view, abdomen tapering posteriorly from tergites 3-8. Tergite 2 shiny black with narrow pale sandy-brown posterior margin, black colouration extending to and enclosing deep brown auditory capsules; tergite 1 black between timbals; tergites 3-8 with clearly defined mid-dorsal, black patches giving overall appearance of a broad, black dorsal fascia; each individual patch tending to widen posteriorly, but not quite reaching intersegmental membrane; ventrolateral margin of tergite 2 with deep brown, irregular patch extending across tergite but not intersegmental membrane; tergites otherwise pale sandy-brown with narrow, pale orange bands lining anterior margins of intersegmental membranes of tergites 3-7. Sternites II-VIII uniformly pale sandy-brown except for a small deep brown to black area located medially between sternites II and III.

Genitalia. (Fig. 12) Pygofer black dorsally grading to dark brown mid-laterally, otherwise pale sandy-brown grading to brown on upper lobes. Upper pygofer lobes in lateral view broad, gently decurved, apically moderately rounded but posterioventral corner more acutely-rounded; aedeagus with moderately long, but gently curved theca, sharply pointed and ornamented apically, with complex sclerotised curved flanges; pseudoparameres very small, originating near thecal base.

FEMALE. (Plate 2D) Overall colouration and markings very similar to male except genae shiny black with distinct sandy-brown margins. Mesonotum with black lateral sigillae narrowing and posteriorly extending into area between anterior and posterior arms of cruciform elevation; pale sandy-brown lateral mesonotal margins and zones between lateral and submedial sigillae broader. Legs markings similar to male, but extent and intensity of brown fasciae reduced. Abdomen: tergite 2 black dorsally extending and narrowing ventrally along anterior margin, just reaching auditory capsule, dorsal halves of which are dark brown; remaining colour medium orange-brown; black anterior bands on tergites

3-8 expanded dorsally, becoming progressively reduced in width and dorsal extent towards tergite 8; tergites 3 and 4 with small brown lateral patches; remaining colouration of tergites 3-7 pale to medium orange-brown, browner towards ventral margins; remaining colour of tergite 8 paler; tergite 9 with broad, black, dorsal fascia, somewhat irregular in shape, sharply narrowing to a point posteriorly; rest of tergite sandy-brown, becoming paler ventrally, with small medium-brown, diffuse spot (stigma) submedially, approximately two-thirds along length of tergite. Sternites uniformly pale sandy-brown. Distinct brown, anterior infuscation on hind wing anal cells 2 and 3. Ovipositor sheath extending ~0.8mm beyond apex of tergite 9.

MEASUREMENTS. N = 14♂, 1♀. Ranges and means (parentheses). *BL:* ♂, 10.7-12.4 (11.5); ♀ 11.0. *FWL:* ♂ 11.3-13.0 (12.1); ♀ 12.7. *HW:* ♂ 2.9-3.3 (3.1); ♀ 3.4. *PW:* ♂ 3.3-3.6 (3.4); ♀ 3.5. *AW:* ♂ 3.6-3.9 (3.7); ♀ 3.6. *FWL/BR:* ♂, 2.40-2.63 (2.54); ♀ 2.55.

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5) Known from the highlands of the Mt Moffatt section of Carnarvon NP, including the adjacent Chesterton Range, southern-central Queensland. Specific localities include the Park Headquarters, "The Tombs", North-west Road, and near Marlong Arch. It is found in grassland, including spinifex, associated with open eucalypt woodland. The associated soils are shallow quartzose sands and boulders, with local alluvial derived sandy soils. These are derived from Jurassic quartz sandstones of the Precipice sandstone and Boxvale Sandstone Formations. This cicada is a cryptic and mobile species. Its song, which is quite distinct from the previously described *Graminitigrina* species, is described in detail below in the song descriptions. The available records range from November to January, following significant rains.

ETYMOLOGY. Derived from Carnarvon National Park, in which the type locality is located.

Graminitigrina triodiae sp. nov.
(Figs 5, 13, 14, 36-40, Plate 2E–F, Table 6)

Urabunana sp.: Dunn, 2002: 26-27.

MATERIAL. HOLOTYPE: ♂, QMT133336, 1.6km NNE Mierowave Tower, Canns Camp track, Burra Ra., ~16km E. Torrens Ck, N.Q., AE, 6 Feb 2006. 20°42.82'S 145°10.63'E, Photog. Spm PS1572.

PARATYPES. 1♂, same data as holotype, 5.ii.2006, recorded (box); 15♂, 1♀, same data as holotype; 1♂, same data, recorded (box); 3♂, 1♀, same data, 7.ii.2006; 1♂, 1♀, same data, 8.ii.2006 (AE). 1♂, same data, 8.ii.2006; 1♀, same data, 6.ii.2006 (ANIC). 1♂, same data, 8.ii.2006 (BMNH). 1♂, same data, 8.ii.2006 (MSM). 1♂, Burra Range Telecom Tower, N. Qld., 12.ii.1994, K.L. Dunn & M.F. Braby (JM). 1♂, 1♀, same data (KLD).

DESCRIPTION. (Male). Figs 13, 14, Pl. 2E. *Head.* Supra-antennal plate and vertex shiny black with 2 small brown spots anteriorly, adjacent to pedicels of antennae; short triangular sandy-brown fascia extending from between lateral ocelli, widening towards and extending to posterior margin of head; short sparse dorsal golden pubescence. Postclypeus, including dorsal surface, shiny black with small, pale sandy spot dorsally on midline and sandy-brown margin which extends only slightly along transverse grooves; scattered short golden pubescence; mandibular plate and genae shiny black with long and short golden pubescence. Ocelli rose red. Compound eyes medium to dark brown. Anteclypeus shiny black covered by short golden pubescence, especially along lateral margins; rostrum medium brown grading to black apically. Antenna black to deep brown with brown pedicel.

Thorax. Pronotum shiny black, pale sandy-brown along lateral margins, extending and narrowing anteriorly to beneath posterior margins of compound eyes; sandy-brown central fascia extending to and narrowing towards anterior pronotal margin, but not reaching posterior margin; pronotal collar shiny black with very narrow sandy posterior edges; lateral angles of pronotal collar markedly ampliate; pronotum with short golden pubescence. Mesonotum predominantly black due to nearly complete coalescence of black submedian sigillae with very broad black lateral sigillae, separated only by a narrow, brown, curved line that extends to apices of anterior arms of cruciform elevation; black colouration extending between anterior arms of cruciform elevation; lateral mesonotal margins pale sandy-brown, extending to wing grooves; cruciform elevation pale yellow-orange grading to sandy-brown toward posterior margin; areas between anterior and posterior arms of cruciform elevation black anteriorly, pale sandy-brown posteriorly.

Wings. Venation pale sandy-brown becoming dark brown towards and around apical cells; costal vein translucent with pale brown colouration developed distally, very narrow, brown sclerotised anterior margin; apex of fore wing with distinct brown infuscation extending, although paler, to approximately apical cell 5 and ulnar cells 1 and

TABLE 6. *Graminitigrina triodiae* - summary of calling and ratchet song parameters. Data compiled from separate field and container recordings of five insects (Burra Range).

	Calling Song		
A. Chirp phrases			
(i) Chirp lengths (ms) -			
7 diplosyllables - field recordings	190(177-210)[1]		
8 diplosyllables - field recordings	202(148-225)[1]		
9 diplosyllables - field recordings	219(183-252)[1]		
9 diplosyllables - container recordings	340(255-386)[1]		
10 diplosyllables - field recordings	266(251-281)[1]		
10 diplosyllables - container recordings	376(305-436)[1]		
11 diplosyllables - container recordings	359(354-363)[1]		
(ii) Chirp repetition rates (ms)			
Field recordings	374(233-445)(1)[2.7 Hz(4.3-2.2Hz)][2]		
Container recordings	623(529-744)(1)[1.6 Hz(1.9-1.3Hz)][2]		
B. Click phases (= diplosyllables)			
(i) Inter-diplosyllable intervals (ms)			
Diplosyllables per chirp	8 diplosyllables	9 diplosyllables	10 diplosyllables
Diplosyllables - 1 to 2	49.5(43-57)[20 Hz][2]	55.1(44-66)[18 Hz][2]	49.1(45-59)[20 Hz][2]
2 to 3	38.0(32-44)[26 Hz][2]	37.4(34-39)[27 Hz][2]	42.8(41-45)[23 Hz][2]
3 to 4	29.9(27-33)[33 Hz][2]	29.2(23-32)[34 Hz][2]	36.4(35-38)[27 Hz][2]
4 to 5	24.1(23-26)[41 Hz][2]	24.1(20-26)[41 Hz][2]	30.9(29-33)[32 Hz][2]
5 to 6	20.2(19-22)[50 Hz][2]	20.6(18-22)[49 Hz][2]	26.1(25-27)[38 Hz][2]
6 to 7	16.2(15-17)[62 Hz][2]	17.0(14-18)[59 Hz][2]	22.4(22-23)[45 Hz][2]
7 to 8	14.4(14-15)[69 Hz][2]	13.1(11-14)[76 Hz][2]	18.6(18-19)[54 Hz][2]
8 to 9	-	12.4(11-14)[81 Hz][2]	15.1(13-17)[66 Hz][2]
9 to 10	-	-	14.0(13-15)[71 Hz][2]
(ii) Diplosyllable structures			
Inter-hemisyllable intervals (ms)	4.1(3.5-5.1)(1)[244 Hz][2]		
Lengths of initial hemisyllables (ms)	0.93(0.64-1.3)[1]		
Lengths of second (dominant) hemisyllables (ms)	3.5(3.3-3.6)[1]		
Total lengths of diplosyllables (ms)	7.6(6.8-8.8)[1]		
C. Dominant frequency (kHz)	8.15 (7.95-8.55) [1]		
D. Click phases (=diplosyllables)	**Ratchet Song**		
(i) Repetition rates (ms)	36.3(27-45)(1)[27.5 Hz(37-22Hz)][2]		
(ii) Diplosyllable structures			
Inter-hemisyllable intervals (ms)	3.6(3.4-3.7)(1)[278 Hz][2]		
Lengths of initial hemisyllables (ms)	1.5(0.84-2.0)[1]		
Lengths of second (dominant) hemisyllables (ms)	3.7(3.3-4.0)[1]		
Total lengths of diplosyllables (ms)	7.2(7.0-7.4)[1]		
Lengths of high amplitude pulse doublets (ms)	0.76(0.73-0.81)[1]		
E. Dominant frequency (kHz)	8.08 (7.90-8.30) [1]		

[1]Figures are means and (ranges). [2]Equivalent frequency values [Hz] of ranges or means.

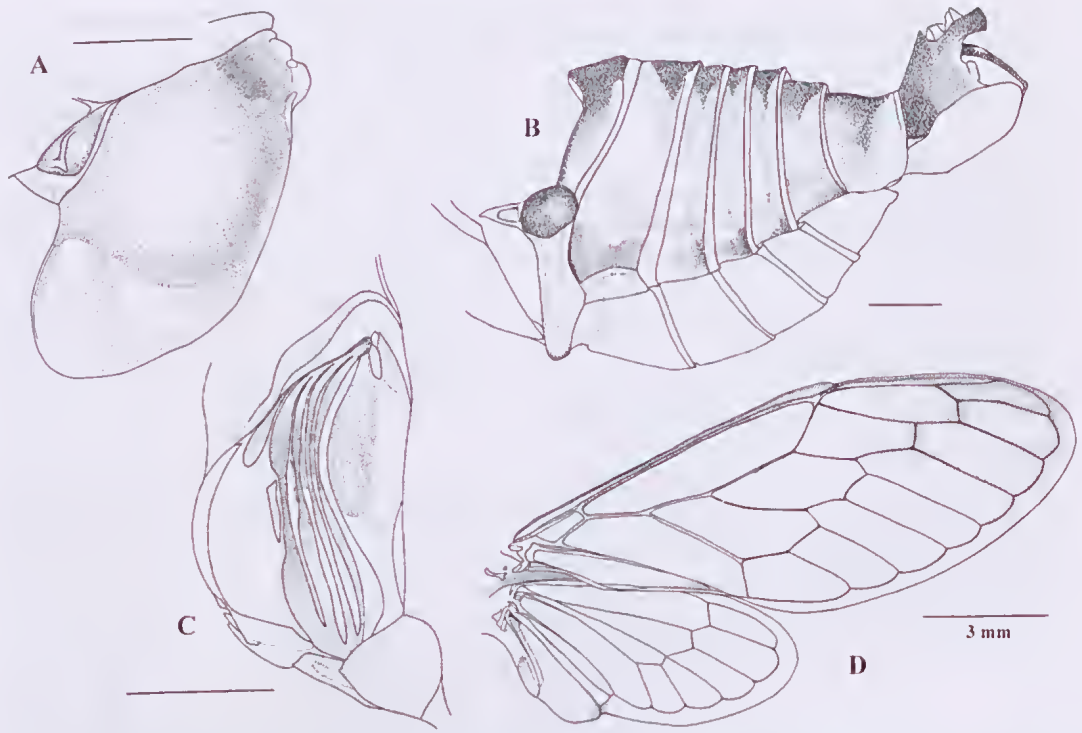

FIG. 13. *Graminitigrina triodiae* sp. nov. Burra Range section of White Mountain National Park. A, right operculum; B, lateral abdomen view; C, timbal (posterior margin at right, dorsal edge at top); D, fore and hind wings. Scale bars 1mm, except wings (3mm).

2. Hind wing with off-white to pale brown plaga extending along margins of vein 3A; small brown infuscation at apex vein 3A, extending slightly proximally along vein; veins 2A and especially 3A distinctly orange-brown; 5 apical cells.

Legs. Fore coxae with most of anterior face dark brown to black; lateral faces with central deep brown to black fascia, otherwise pale sandy-brown; mid and hind coxae mostly deep brown to black, apices pale sandy-brown; fore trochanters and femora with deep brown to black fasciae on anterior and posterior faces, otherwise sandy-brown to brown; mid and hind trochanters pale brown with small deep brown patches especially on anterior faces; mid and hind femora pale sandy-brown to brown with black to deep brown faciae along posterior faces; fore tibiae and tarsi mainly black to deep brown; mid to hind tibiae and tarsi pale brown to brown, with dark brown fasciae along dorsal margins, bases and apices of tarsi deep brown; claws brown.

Opercula. Slightly elongated, disto-medial margins slightly tapered and rounded, gently inclined towards abdominal midline; opercula sandy-brown with clearly defined black patch near basal crests; basal two thirds of operculum strongly convex, domed; spikes on meracantha small, sharply pointed, not extending across opercula plates; distal operculum gently undulate, not reaching anterior margin of sternite II in lateral view.

Timbals. Long ribs 1-4 fused ventrally, and dorsally to basal spur; long rib 5 very short but robust, not extending ventrally near anterior short rib; long rib 4 especially broad and robust, much more so than long ribs 1-3; anterior-most short rib robust, short ribs between long ribs 1-4 very thin and relatively poorly sclerotised; unusually large area of uninterrupted white resilin on timbal plate extending from long rib 4 to anterior timbal margin; narrow dome on timbal plate with distinct ridges.

Abdomen. Maximum width across tergite 3 slightly greater than across auditory capsules;

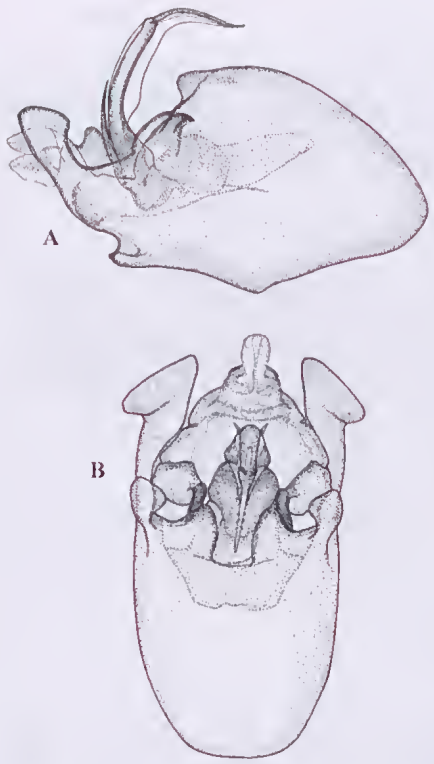

FIG. 14. *Graminitigrina triodiae* sp. nov. Pygofer and male genitalia, lateral (A) and ventral views (B). Specimen from Burra Range section of White Mountains National Park. Length of pygofer, 2.6mm.

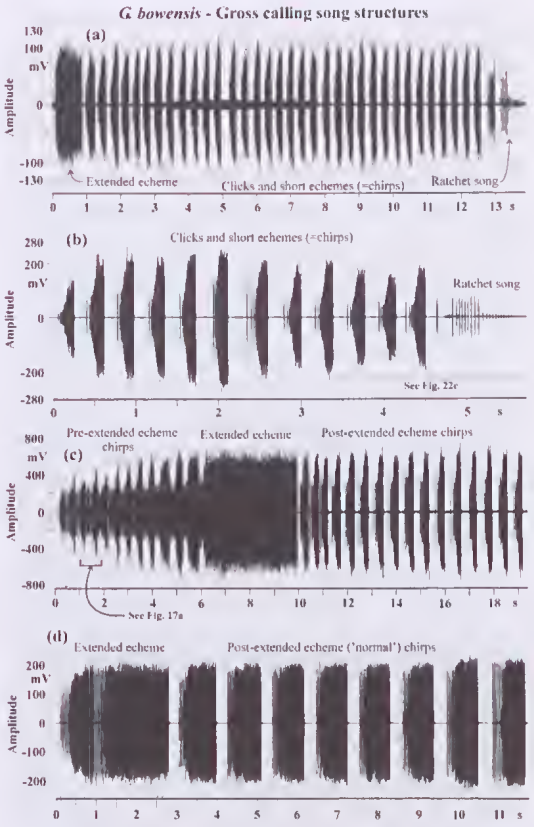

FIG. 15. *Graminitigrina bowensis* sp. nov. Waveform plots showing gross temporal structures of calling songs; (a, c, d), extended echemes; (c), pre-extended echeme chirp phrases; (a-d), post-extended echeme chirp phrases; (b), ratchet song. Recordings (a-c) of insects from Flagstaff Hill, Bowen; (a-b), field recordings with parabola, filtered (IIR) to 8 kHz; (c), unfiltered container recording; (d), unfiltered container recording of insect from Croydon.

in dorsal view, abdomen progressively tapering posteriorly from tergites 3-8. Tergite 2 shiny black to deep brown, with narrow sandy-brown posterior margin; dark colouration extending to and covering auditory capsules, central regions of which are deep brown; tergite1 shiny black to deep brown between timbals; tergites 3-8 with clearly defined black to deep brown mid-dorsal patches; individual patches widest medially, narrowing both anteriorly and posteriorly, reaching but not extending posteriorly across intersegmental membranes; dark patches decreasing in size and intensity from tergite 3-8; ventrolateral margins of tergites 3-7 with irregular patches of deep brown to brown colouration, becoming smaller and weaker in intensity on tergites 6 and 7; tergites 3-7 otherwise sandy-brown to brown, becoming orange brown along the posterior half of each tergite; intersegmental membranes conspicuously pale yellow-brown; tergite 8 mostly sandy-brown, with darker dorsal area. Sternites II to VIII pale sandy-brown, slightly more intense along intersegmental membranes; small black median area on sternite II just extending to sternite III.

Genitalia. (Fig. 14) Pygofer shiny, black dorsally grading to deep brown laterally and posteriorly; upper pygofer lobes in lateral view broad, decurved, apices expanded and rounded. Aedeagus with gently curved theca, curvature more pronounced and gently sinusoidal distally, apex not significantly ornamentated but with four very small pairs of spines; poorly sclerotised, but distinct flange along inner curved surface, and inconspicuous, poorly sclerotised flange along outer curved margin of theca; pair of short, but clearly defined pseudoparameres, originating near thecal base.

FEMALE. Pl. 2F. Similar to male in overall colouration and patterning except: head with narrow sandy-brown anterior margin along supra-antennal plate and vertex, more conspicuous pale sandy-brown midline on anterior face of postclypeus; genae with narrow sandy-brown lateral margins; pronotum shiny black with broader pale sandy-brown central fascia extending from anterior to posterior margin, splaying out along posterior margin. Mesonotum with narrower black lateral sigillae which extend to anterior arms of cruciform elevation; submedian sigillae more clearly defined, fused medially, resulting narrower median black fascia extending and widening posteriorly to between anterior arms of cruciform elevation; sandy-brown areas between sigillae more extensive. Legs markings similar to male but dark fasciae reduced in area and intensity. Abdomen: tergite 1 medium brown dorsally; tergite 2 with black dorsal area which narrows and extends submedially along anterior margin and does not extend to auditory capsule; rest of tergite 2 and auditory capsule pale sandy-brown; tergites 3-8 with black dorsal patches (often more clearly defined than in males), that become progressively smaller in area towards tergite 7; dark patches not extending across intersegmental membranes on tergites 3-6, and not reaching intersegmental membrane on tergite 7; patch on tergite 8 distinctly transverse, extending laterally along anterior margin; small and relatively inconspicuous brown markings along ventro-lateral margins of tergites 3-5, becoming smaller and paler towards tergite 5; tergites 3-8 mainly sandy-brown laterally and submedially along anterior margins, becoming a conspicuous chestnut-brown submedially along posterior margins and extending to intersegmental membranes; the latter are sandy-brown on tergites 3 to 6; tergite 9 with pair of broad, irregular-shaped submedian fasciae of very variable brown colouration, tending to be darker posteriorly; fasciae extend to, and coalesce near posterior margin of tergite; a small, submedian, brown spot situated towards posterior of tergite; tergite 9 colouration dominantly sandy-brown to brown dorsally, with localised chestnut-brown area along disto-ventral margins. Sternites pale sandy-brown. Ovipositor sheath black distally, extending 0.9-1.2mm beyond apex of tergite 9.

MEASUREMENTS. N = 25♂, 4♀. Ranges and means (in parentheses). *BL*: ♂, 11.0-14.1 (12.6); ♀, 12.2-13.5 (12.6); *FWL*: ♂, 11.7-14.0 (13.2); ♀, 13.0-13.7 (13.3); *HW*: ♂, 3.0-3.6 (3.3); ♀, 3.3-3.5 (3.4); *PW*: ♂, 2.6-3.2 (3.0); ♀, 2.9-3.2 (3.1); *AW*: ♂, 4.0-4.6 (4.3); ♀, 3.6-4.0 (3.8); *FWL/BR*: ♂, 2.43-2.65 (2.53); ♀, 2.41-2.48 (2.46).

DISTRIBUTION, HABITAT AND BEHAVIOUR. (Fig. 5) Known only from the upland desert plateau area (Alice Tableland Province) of the Burra Range section of White Mountain National Park, approximately 16km E of Torrens Creek township, northern Queensland. The specific habitat is developed on a ferruginous sand plain, overlying a laterite profile, itself developed on quartzose sandstones and siltstones of the Warang Sandstone Group of probable Triassic age. The vegetation is dominated by *Eucalyptus similis* Maiden woodland with spinifex understory (*Triodia pungens* R. Br.) on which this cicada is restricted. In common with other *Graminitigrina* species, adults are very wary, mobile and fast flying. Singing occurs in the morning, the time of initiation and cessation depending on specific weather conditions. When sunny, singing starts at approximately 0730 hrs and continues, becoming progressively more sporadic, until late morning. When part cloudy, singing starts and finishes later, extending sporadically to mid afternoon. Adults are superbly cryptic, and when physically touched, drop down into the spinifex where they are completely concealed. Dunn (2002) provides a description of the mating behaviour, including wing flicking (or 'clapping'). Available records, during which active emergence was occurring, are only for February. Although the type series was collected from one specific locality in the Burra Range, aural records indicate that it occurs, albeit in very localised populations over 3.1km along the Canns Camp track in the Burra Range NP. This species, as further noted below in the song descriptions, has close similarities to *G. carnarvonensis*. It is of significance to note that both occur on the Great Dividing Range, on soils developed on sandstone basements, although separated by a linear distance of 550km.

ETYMOLOGY. From *Triodia*, the generic name of the spinifex grass on which this species is found.

ANALYSES OF THE SONGS OF *GRAMINITIGRINA* CICADAS

Species of *Graminitigrina* cicadas tend to separate into three groups according to their songs; the two northern species (*G. karumbae* and *G. bowensis*); *G. bolloni*; and *G. carnarvonensis* and *G. triodiae*. The calling songs of both *G. bowensis* and *G. karumbae* are dominated by distinctive sharp, repetitive chirp phrases, superficially similar in gross structures. The songs of *G. bowensis*,

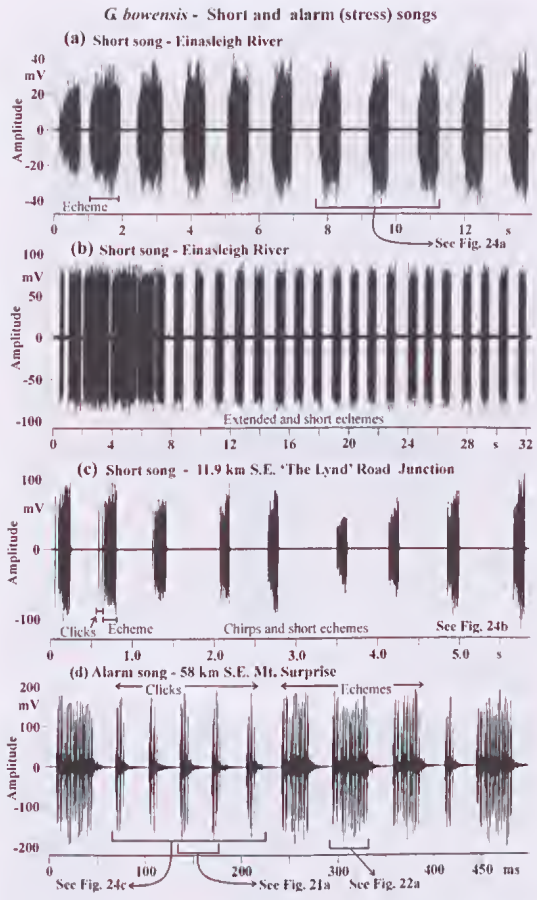

FIG. 16. *Graminitigrina bowensis* sp. nov. Waveform plots of short songs (a-c) and alarm song (d). In the short songs, sets short echemes, of variable lengths, with either very few or more usually no preceding clicks are shown. The chirps in (c) are from the end of a sequence. The alarm song shows clicks and very short echemes which exhibit no regular temporal pattern of emission. Data in plots (a-b), filtered (IIR) to 0.5 kHz; (c-d), unfiltered. (a-b), container recordings from Einasleigh River crossing (W. of Mt Surprise); (c), container recording from 11.9km SE of "The Lynd" road junction; (d), open net recording in the field from 58km S.E of Mt Surprise.

however, exhibit variability, some of which appears to be regional. This is most notable in the population from Flagstaff Hill at Bowen (type locality) in which the calling song possesses an additional extended sharp buzzing phrase, referred to here as an 'extended echeme'. This song phrase is very common in the Bowen population, and has been observed in the Croydon population, but has not been encountered in other populations of this species, or in *G. karumbae*. As documented below, songs of *G. bowensis* show three additional song variants, the 'short song', the 'alarm (stress) song', and the 'ratchet song'. This latter song type has been observed in four of the species of *Graminitigrina* (*G. carnarvonensis* the exception), although electronically recorded only for *G. bowensis* and *G. triodiae*. *Graminitigrina bolloni*, *G. carnarvonensis* and *G. triodiae* have songs comprising repetitive sequences of short chirps and clicks, with distinctive temporal characteristics that clearly differentiate them from *G. bowensis* and *G. karumbae*.

Graminitigrina species are generally restricted to rough grassland, including spinifex and low heath, within open, sometimes disturbed woodland. The dominant yellowish and black colouration of adults merges well with the associated green/brownish-yellow grass and heath vegetation. Adults sit and sing on grass stems at all levels, often among seed clusters, or within foliage of the heath. Calling songs extend for 1 to 2 minutes, or slightly longer. The adults then abruptly cease their calling songs, which are then replaced by the 'ratchet song' (excepting *G. carnarvonensis*) which continues as the cicada flies to a new singing location; then calling song emission is again initiated. This 'sing and fly' behaviour occurs from early morning (about 0730 hrs a.m.) in open sunny conditions, and continues to mid morning, with song production becoming more sporadic towards late morning, and ceasing altogether by midday to early afternoon. In between singing periods, and after singing has ceased, the cicadas sit quietly and cryptically, presumably feeding in the grassland/heathland, with no obvious movement unless disturbed.

SONG DESCRIPTIONS

1. *G. bowensis*

Four song types are recognised in this species: (a) The **normal calling song**, referred to above, consisting of repeated chirps, with an additional **extended ('buzzing') echeme**, usually, but not always preceding the repeated chirp song phase (Fig. 15a-c). The extended echeme is a characteristic feature of the songs of the Bowen population, but has also been noted in the Croydon population (Fig. 15d). (b) Sporadically emitted short sequences of rapidly emitted chirps, referred to here as the **'short song'**, sometimes with embedded, slightly longer echemes (Fig. 16a-c). This song type has only been encountered twice, each in populations very low in numbers and

believed to be in decline. In these situations, adults appeared to be relatively sedentary, calling with sporadic, short and sharp song sequences, with or without flight. (c) A distinctive **alarm (stress) call**, given when an adult is trapped in a spider web, or relatively tightly confined within a net (Fig. 16d). This song consists of a monotonous, continuous sequence of rapidly repeating clicks and short chirps. (d) The **ratchet song** accompanying flight to a new song location (Fig. 15a, b). Parameters of each song type are listed in Table 2.

1A. *Calling Song.*

Bowen locality. The extended ('buzzing') echeme phase occurs either at the beginning or later during the song, and lasts from approximately1 to 7.5s, and is preceded by (except where occurring at start of song) and followed by sequences of continuous short, rapid chirps (Fig. 15). Each 'chirp phrase' consists of a set of discrete clicks which progressively merge and coalesce to form a short 'chirp echeme' which increases in amplitude during emission. The chirp phrases that precede the extended echeme phase actually differ in detailed temporal characters from those chirp phrases that follow the extended echemes. Descriptions that follow therefore distinguish pre- and post-extended echeme chirps. This latter chirp-type constitutes the typical chirp calling songs that are emitted without any accompanying extended echeme phase.

(i) Pre-extended echeme chirp phrases. (Table 2; Figs 15c; 17a-c). These consist of a series of repeated short echemes, each showing progressively increasing amplitude and increasing length, the latter ranging from 0.21 to 0.49 s. Between each short echeme occur sets of continuous clicks, 7 to 10 in number, whose repetition rates become sequentially more rapid both towards the following extended echeme, and towards each following short echeme. Click repetition rates range between 26 s^{-1} (initial set) to 59 s^{-1} in the final sets immediately prior to the extended echeme. These compare with short chirp echeme repetition rates of 1.5 to 2.5 s^{-1}, these decreasing as the extended echeme is approached.

Each click, details of which are shown in the expanded waveform plot (Figs 17b), is interpreted to comprise 2 syllables, the click thereby representing a single macrosyllable. In some click macrosyllables, the structures suggest a third syllable (as in Fig. 17b), but based on examination of many such click macrosyllables, two syllables

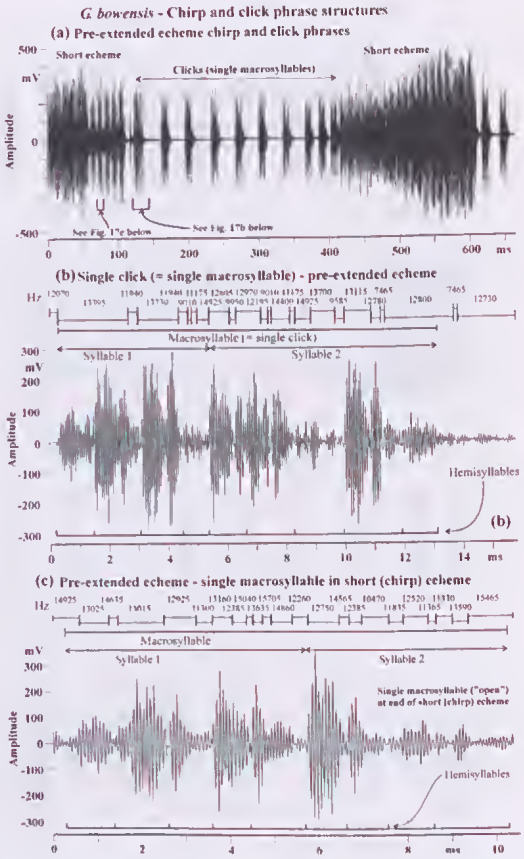

FIG. 17. *Graminitigrina bowensis* sp. nov. Pre-extended echeme chirp phrases. (a), waveform plot showing sequence of clicks between adjacent short chirp echemes. High resolution time expanded waveform plots of; (b) a single click (see location in (a) above) showing details of syllable and hemisyllable structures; and (c), a single macrosyllable within a short echeme (pre-extended echeme chirp phrase; see location in (a) above). (b) and (c) show the sequential changes in pulse frequencies as measured from detailed pulse counts. These are tabulated within the marked segments above each plot. Container recordings from Flagstaff Hill, Bowen filtered (IIR) to 0.5 kHz.

are here considered the most consistent. Each syllable is resolved into 4-5 hemisyllables. The initial hemisyllable tends to be relatively low amplitude, while partial overlap of adjacent hemisyllables is common. Low amplitude hemisyllables also occur, apparently compressed between adjacent higher amplitude hemisyllables, their relative positions within each macrosyllable being consistent relative to the same sets of hemisyllables in other macrosyllables. Syllable lengths

Plate 1. A–E, *Graminitigrina bowensis* sp. nov. A, holotype male, Flagstaff Hill, Bowen; B, male, Croydon. Total body lengths 12.6 and 12.2mm, respectively; C, male, Einasleigh River crossing, 35km W. Mt Surprise; D, male, 11.9km SE "The Lynd" Road junction; E, female, Flagstaff Hill, Bowen. Total body lengths 12.2, 11.2 and 11.7mm, respectively; F–H, *Graminitigrina karumbae* sp. nov. F, male, 10.7km E. Heathlands, Northern Cape York peninsula; G, holotype male, 2km E. Karumba Village, Karumba, southeastern Gulf of Carpentaria; H, female, 2km E. Karumba Village, Karumba. Total body lengths 12.7, 13.0 and 11.2mm, respectively.

Plate 2. A–B, *Graminitigrina bolloni* sp. nov. A, holotype male; B, female, Both from 0.7km E. Bollon. Total body lengths 12.1 and 12.7mm, respectively; C–D, *Graminitigrina carnarvonensis* sp. nov. C, holotype male, Marlong Arch, Mt Moffatt National Park; D, female, Park Headquarters, Mt Moffatt National Park. Total body lengths 11.9 and 11.0mm, respectively; E–F, *Graminitigrina triodiae* sp. nov. E, male; F, female. Both from Burra Range section of the White Mountain National Park, 1.6km NNE of Microwave Tower. Total body lengths 13.0 and 12.2mm, respectively.

range between 5.1-8.2 ms, and macrosyllables 13.0-14.1 ms.

Detailed measurements of the pulses shown in the waveform plots (e.g. Fig. 17b) reveal a wide range of measured frequencies ranging between 7465 to 16020 Hz, developed across time domains between 0.1-2.0 ms in length, consistent with frequencies exhibited by the amplitude spectra (Fig. 23). The higher amplitude hemisyllables tend to exhibit higher frequencies compared to the inter-hemisyllable intervals and macrosyllable tails. Of particular note are the rapid frequency changes on time scales of <1 ms.

Macrosyllable structures within the short chirp echemes (Fig 17c) are similar in structure to the click macrosyllables, again inferred to comprise

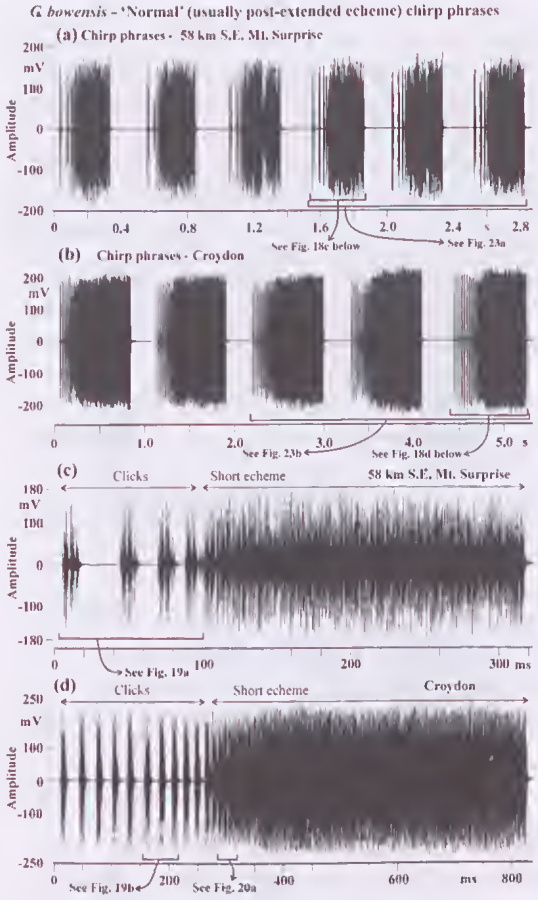

FIG. 18. *Graminitigrina bowensis* sp. nov. (a-b), Waveform plots of chirp phrases within calling songs that have no extended echemes (therefore equivalent to post-extended chirp phrases). These show the sequences of clicks preceding each short echeme. (c-d), Expanded time scales of selected segments from each of the previous plots of the clicks and their coalescing into the short echeme (locations shown in (a) and (b), respectively). Unfiltered container recordings. (a, c), from 58km SE Mt Surprise; (b, d), from Croydon.

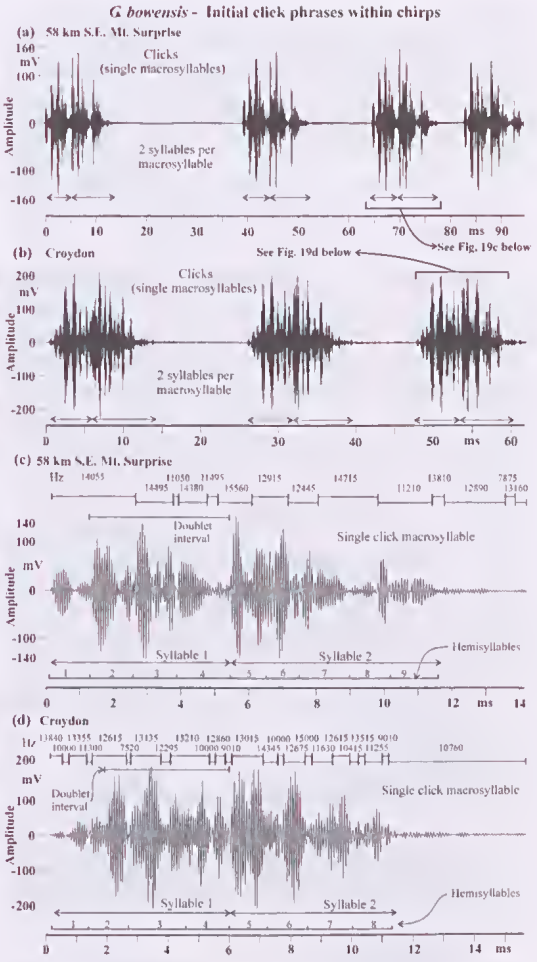

FIG. 19. *Graminitigrina bowensis* sp. nov. (a-b), time expanded waveform plots of click macrosyllables preceding the short echemes within a chirp phrase (post-extended echeme) of the calling song, showing the presence of two syllables within each macrosyllable, and the higher frequency carrier pulses. (c-d), high resolution time expanded waveform plots of individual click macrosyllables, showing detailed syllable wave structures, the definition of syllable intervals (shown by the arrowed lines in a-d) and doublet intervals (e-d), and the sequentially changing frequency domains measured from the detailed pulse structures (tabulated above each plot). Unfiltered container recordings. (a, e), 58km SE Mt Surprise; (b, d), Croydon.

2 syllables, each with 3-5 hemisyllables. Macrosyllable lengths range between 9.6-10.7 ms, shorter than observed for the clicks, while syllable lengths lie between 3.8-5.5 ms. Pulse measurements within the waveform plots indicate frequency ranges between 10470-15705 Hz, with the dominant, high amplitude hemisyllable phases between 12385-13160 Hz. The lower amplitude, inter-hemisyllable domains include both higher and lower frequencies. Again, rapid frequency fluctuations occur on time scales between 0.1-1.0 ms. The echeme structures are interpreted to represent coalesced and slightly compressed click macrosyllables.

(ii) Post-extended ('normal') echeme chirp phrases. (Table 2; Figs 15, 18) These consist of sets of discrete clicks which progressively merge

and coalesce into the short chirp echemes, each increasing in amplitude during emission. The clicks range from 0 to 5 in number (rarely zero); chirp lengths range between 0.15-0.46 s, with repetition rates between 2.2-3.3 s^{-1} (field parabola recordings in direct sunshine), compared to 0.9-2.85 s^{-1} (container recordings); the highest rates occur closest to the preceding extended echeme, if present.

Detailed structures of individual clicks, shown in time expanded waveform plots (similar to those shown in Fig.19a, b), suggest a single macrosyllable comprising two syllables (without intervening time gap), with four hemisyllables per syllable, each containing three dominant composite pulses. Macrosyllable lengths lie between 12.7-14.4 ms, syllables between 6.1-7.2 ms, and hemisyllables 0.83-1.7 ms, these values very similar to the pre-extended echeme clicks. Through progressive coalescence, the click macrosyllables merge into the short chirp echemes, each typically comprising between 15-40 macrosyllables. These are similar to those illustrated in Fig. 18c, d, and in Fig. 20b, in which each macrosyllable comprises two syllables, each with 3-4 hemisyllables. Macrosyllable lengths range between 10.0-10.5 ms, syllable lengths between 4.6-5.7 ms, both notably shorter than observed in the clicks, consistent with syllable compression during coalescence.

(iii) Extended echeme phase. (Fig. 15a, d) This is very similar in overall syllable-hemisyllable structures to the short chirp echemes, emphasised by the comparative data listed in Table 2. The implication is that the extended echeme also

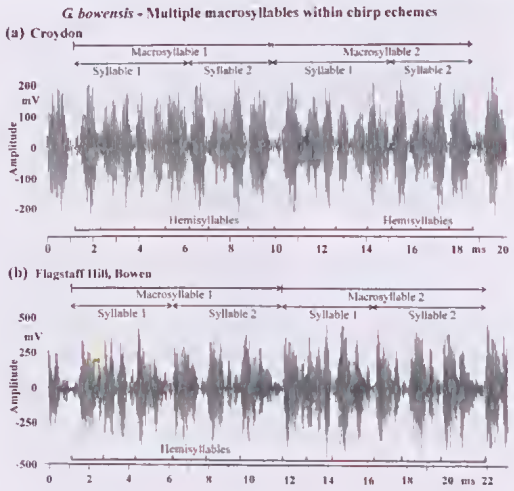

FIG. 20. *Graminitigrina bowensis* sp. nov. High resolution time expanded waveform plots of macrosyllable structures within short chirp echemes of calling songs (post-extended echeme) from (a), Croydon and (b), Flagstaff Hill, Bowen. In both plots, two coalesced macrosyllables are shown, each macrosyllable resolved into two juxtaposed syllables, each of which is further resolved into three to four hemisyllables. The higher frequency carrier pulses are also evident within the plots. Container recordings. (a), unfiltered; (b), filtered (IIR) to 0.5 kHz.

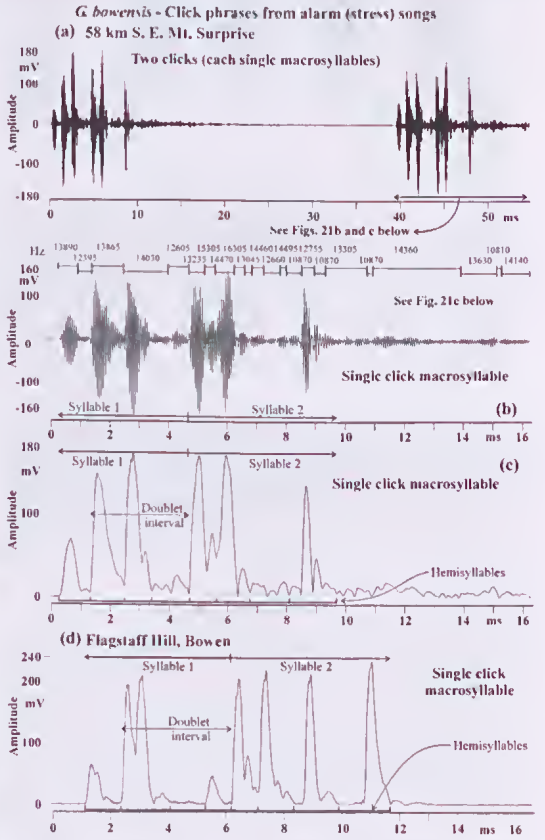

FIG. 21. *Graminitigrina bowensis* sp. nov. Higher resolution time expanded waveform plots (a-b) and envelope curves (c-d) of the clicks within stress song. (a) illustrates two click macrosyllables (locations shown in Fig. 16d), with the second click analysed in greater time expanded detail in (b-c). These show the two juxtaposed syllables, the defined doublet interval, and in (b), the rapid sequential frequency changes within the click macrosyllable, measured from the carrier wave pulse structures. (d), details of a single click of a stress song from Flagstaff Hill, Bowen, showing two coalesced syllables (compare with (c)). Unfiltered recordings made of insects constrained in a net in the field, from 58km SE Mt Surprise and Flagstaff Hill, Bowen.

represents a prolonged coalescence of click phrases.

(iv) Song frequencies. The amplitude spectra derived from multiple chirps are complex, with four groups of peaks commonly occurring between 10.5-11.4, 11.5-12.6, 12.7-13.7 and 14.1-14.9 kHz, with weaker peaks between 15.2-16.7 kHz, seen in both container and field recordings. The estimated dominant frequencies range between 12.6-13.6 kHz (mean 13.12 kHz), these close to the highest amplitude peaks seen in the spectra (e.g. Fig. 23e). The strongest frequency peaks have a tendency to comprise peak doublets, although all peaks are broad due to the presence of numerous closely-spaced line spectra, inferred to represent sets of sidebands of variable frequencies (e.g. see tabulation in Fig. 23c).

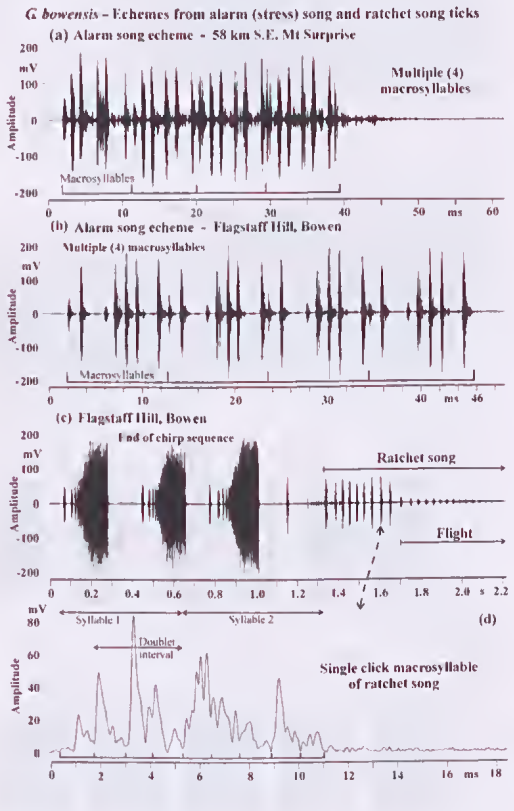

FIG. 22. *Graminitigrina bowensis* sp. nov. (a-b), time expanded waveform plots showing the structures of a single echeme within two alarm songs, each comprising four macrosyllables, from 58km SE Mt surprise (see location of echeme in Fig. 16d), and Flagstaff Hill, Bowen respectively. Unfiltered recordings of insects constrained in a net in the field; (c), waveform plot of ratchet song emitted at end of a normal chirp sequence, occurring immediately prior to, and during flight; (d), high resolution envelope curve showing details of a single click macrosyllable from the ratchet song in (c). (c-d), parabola field recordings from Flagstaff Hill, Bowen, filtered (IIR) to 8 kHz.

1B. Calling Song

Inland localities. (Croydon, Einasleigh River, 58km SE Mt Surprise, and near 'The Lynd" Highway junction) Only in the Croydon population has an extended echeme phase been sporadically heard. The songs from these inland localities mainly comprise monotonously repeated chirp phrases (Figs 15d; 18a-d) whose lengths range between 0.13-1.6 s (Table 2) with repetition rates between 0.5-2.4 s^{-1}, tending to progressively increase, within a given song sequence, during song emission. As in the Bowen population, each chirp consists of a series of initial clicks (up to 21 in number, very rarely zero),

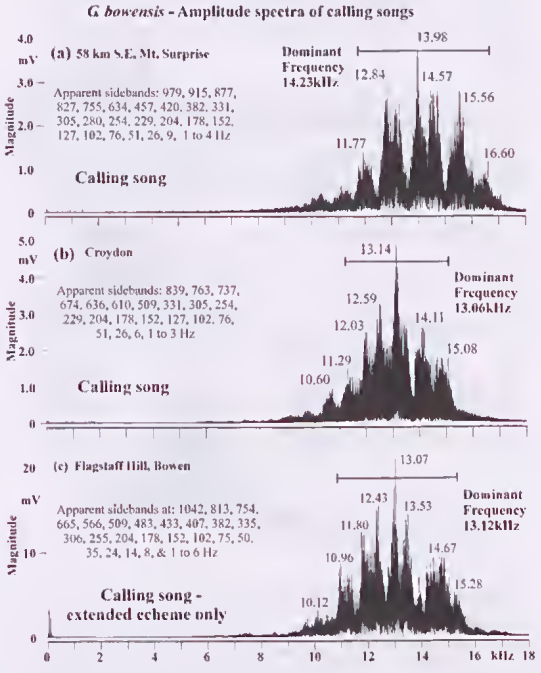

FIG. 23. *Graminitigrina bowensis* sp. nov. (a-e), Amplitude spectra of multiple chirps within calling songs from 58km SE Mt Surprise (see Fig. 18a), Croydon (see Fig. 18b), and Flagstaff Hill, Bowen (extended echeme), respectively. Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. The horizontal bars indicate the high amplitude envelope of each spectrum used to estimate the dominant frequency of each song. Container recordings, unfiltered.

whose repetition rates increase during progressive emission, merging into the following short chirp echeme (Fig. 18c, d).

(i) Clicks. (Fig. 19) Detailed structures seen in time expanded waveform plots are similar to those of the Bowen population. Each click is similarly interpreted as a macrosyllable comprising two juxtaposed syllables, each syllable with 4 to 5 hemisyllables (each with 3 distinct composite pulses). Lengths range between 8.9-11.6, 5.3-6.2, and 1.0-1.9 ms, respectively; the macrosyllable and syllable lengths are slightly shorter than measured in the Bowen songs. Detailed waveform plots show frequency ranges between 7520 to 15560 Hz (Fig. 19c, d), consistent with amplitude spectra (e.g. Fig. 23a, b), and again exhibit rapid frequency alternations on time scales of between 0.1-4.3 ms. The higher amplitude pulses exhibit frequencies in the higher measured ranges, the lower amplitude pulses tending to be characterised by more variable frequencies.

(ii) Short chirp echemes. (e.g. Fig. 20a) These comprise coalesced macrosyllables, with similar pulse structures to those in the clicks (compare Figs 19c, d and 20a). The individual macrosyllables are clearly resolved within the echeme structures, most pronounced in the early echeme structures (cf. Figs 19c, d; 20a).

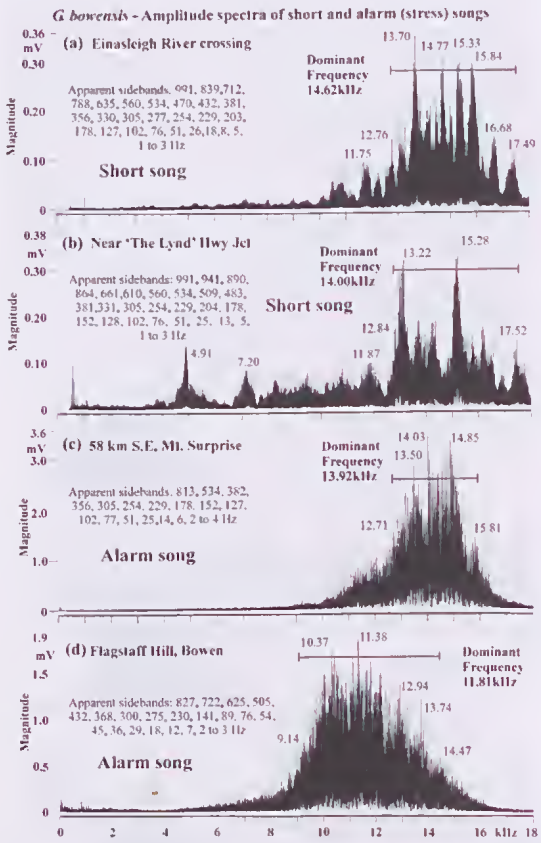

FIG. 24. *Graminitigrina bowensis* sp. nov. (a-b), amplitude spectra of short songs from, (a) Einasleigh River crossing, W. of Mt Surprise (see location in Fig. 16a); (b) 11.9km SE of 'The Lynd' road junction, N. Queensland. Container recordings filtered (IIR) to 0.6 kHz (see location in Fig. 16c). (c-d), amplitude spectra of alarm songs, recorded from insects constrained in a net in the field, from (a), 58km SE Mt Surprise (see Fig, 16d); (b), Flagstaff Hill, Bowen. Unfiltered data. Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. The horizontal bars indicate the high amplitude envelope of each spectrum used to estimate the dominant frequency of each song.

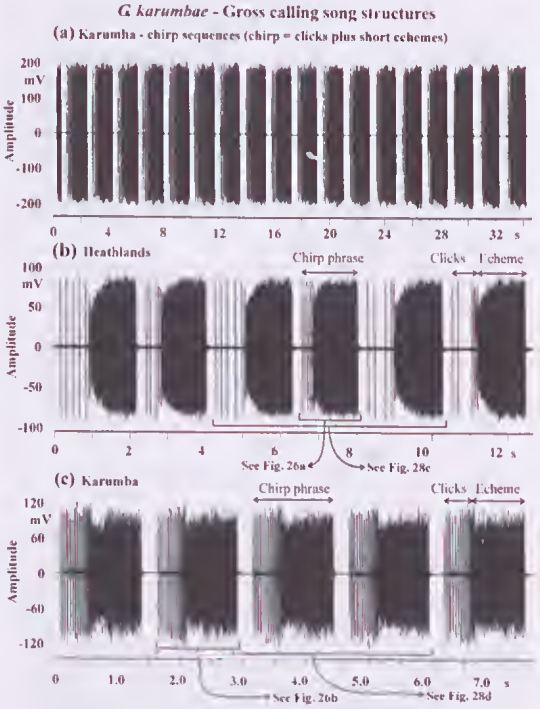

FIG. 25. *Graminitigrina karumbae* sp. nov. Waveform plots of calling songs, showing, (a), gross temporal structures of the chirp phrases, each chirp consisting of initial click sequences followed by the short chirp echeme; (b-c), clicks and their coalescence into the short chirp echemes. (a, c), Karumba, southeastern Gulf of Carpentaria; (b), Heathlands , northern Cape York Peninsula. All based on container recordings, (a, c), unfiltered; (b), filtered (IIR) to 0.5 kHz.

Each macrosyllable is further resolved into two syllables, each with typically 3-4 hemisyllables (noting that the precise delineation of individual hemisyllables becomes less certain within the echemes). Macrosyllable lengths vary between 7.5-11.9 ms, similar to and sometimes shorter than those of the clicks. Syllable and hemisyllable lengths are 3.7-5.7 and 0.95-1.6 ms, also similar to those in the click phases. Although not shown, detailed pulse measurements made in time expanded waveform plots within individual macrosyllables show frequency ranges between 8200-15800 Hz, and rapid alterations of frequencies on time scales varying between 0.1-1.2 ms, similar to the click macrosyllables, and similarly implying rapid changes in the sound

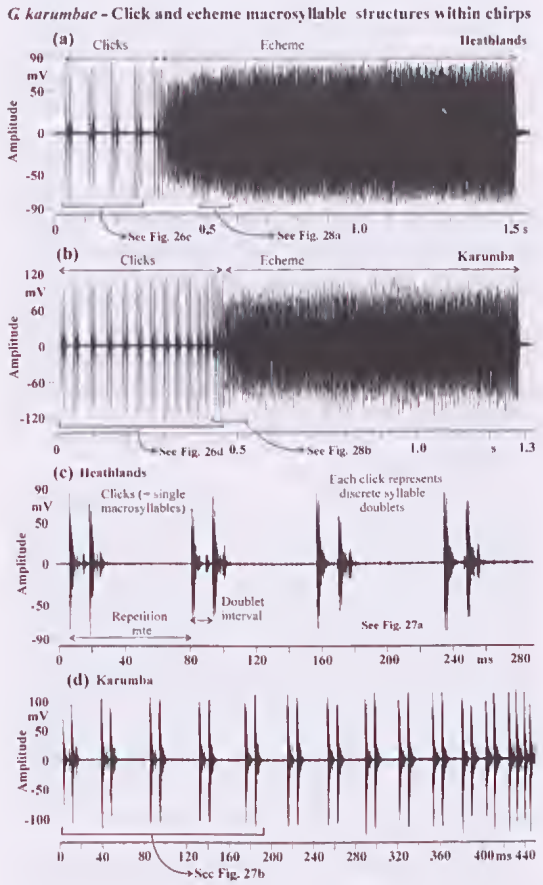

FIG. 26. *Graminitigrina karumbae* sp. nov.. Waveform plots of calling songs showing, (a-b), time expanded plots of the clicks and their progressive coalescence into short chirp echemes; (c-d), higher resolution time expanded waveform plots illustrating more detail of the structures of the clicks. Each click is interpreted as a single macrosyllable made up of two clearly defined high amplitude syllables (syllable pairs). (c) shows the definition of the doublet intervals and repetition length (rate s^{-1}). (a, c), Heathlands, northern Cape York Peninsula; (b, d), Karumba, southeastern Gulf of Carpentaria. Plots based on container recordings, (b, d), unfiltered, (a, c), filtered (IIR) to 0.5 kHz.

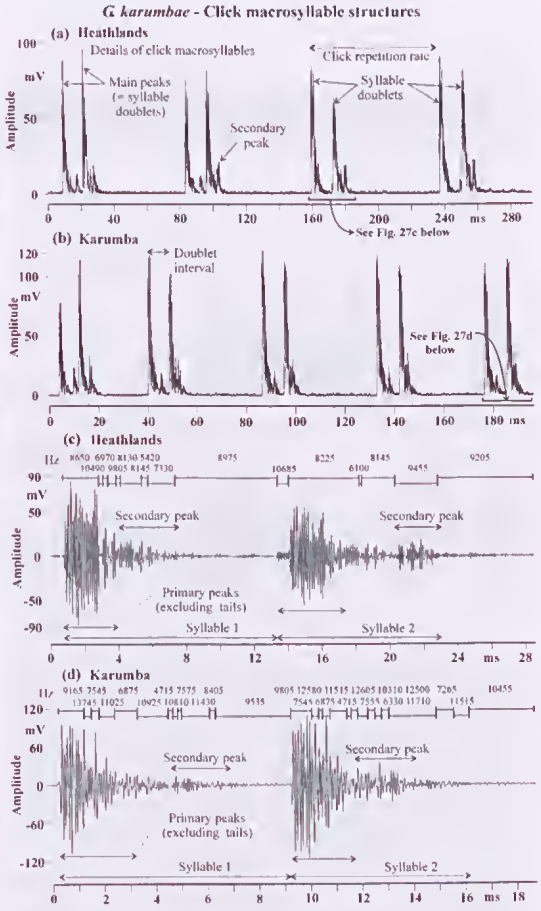

FIG. 27. *Graminitigrina karumbae* sp. nov. Detailed time expanded envelope curves (a-b) and high resolution waveform plots (c-d) of clicks within calling songs. (a-b) illustrate the general form of the syllable pairs. (c-d), shows further details of higher frequency pulse structures within single click macrosyllables, including the resolution of syllable pairs into the higher amplitude 'primary' peaks and weaker secondary peaks, together with the measured sequential frequency changes occurring during the emission of each click, based on pulse counts within the waveform plots (tabulated above each plot). (a, c), Heathlands, northern Cape York Peninsula; (b, d), Karumba, southeastern Gulf of Carpentaria. Plots based on container recordings, (b, d), unfiltered; (a, c), filtered (IIR) to 0.5 kHz.

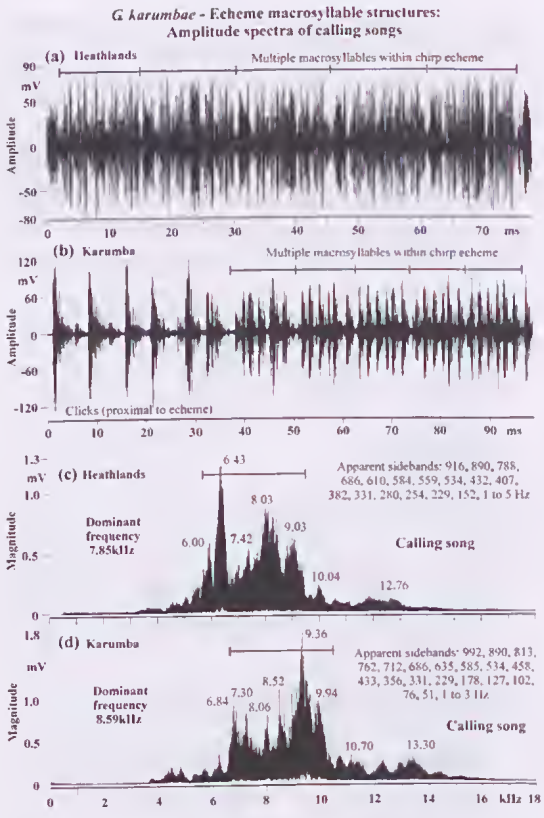

FIG. 28. *Graminitigrina karumbae* sp. nov. Calling song waveform plots showing further details of (a), coalesced multiple macrosyllables within short chirp echeme, the limits of each macrosyllable shown on the accompanying bars (see Fig. 26a for detailed location of plot); (b), transition from discrete syllable doublets (macrosyllables) of the clicks to the coalesced macrosyllables of the following echeme (see fig. 26b for locations of plot); (c-d), Amplitude spectra of the calling songs (see Fig. 25b, c for locations of these spectra). Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. Horizontal bars indicate the high amplitude segment of each spectrum used to estimate the dominant frequency of each song. (a, c), Heathlands , northern Cape York Peninsula; (b, d), Karumba, southeastern Gulf of Carpentaria. Plot based on container recordings, (b, d), unfiltered; (a, c), filtered (IIR) to 0.5 kHz.

radiating structures (e.g. Fonseca and Popov, 1994). The critical aspect is that the various syllable, macrosyllable and hemisyllable structures, and the overall temporal structures of the chirp phrases, are very close to the calling songs from the Bowen locality.

(iii) Song frequencies. (Fig. 23a, b) Amplitude spectra exhibit a series of broad and complex peaks, which tend to define frequency bands between 10.0-10.8, 11.1-11.5, 11.7-12.3, 12.4-13.7, 13.8-14.8 and 15-17 kHz. Dominant frequencies are estimated to be 14.2 and 13.1 kHz (58km SE of Mt Surprise and from Croydon, respectively), very similar to those from Bowen (Fig. 23a). The breadth and complexity of the peaks is again attributed to sets of sideband spectra (details listed in Fig. 23a, b) based on measurements of the spectra. The lower frequency sidebands, below about 0.5 kHz, are reasonably consistent between the three sets of spectra shown in Fig. 23. The broader peak groupings referred to above feasibly result from sets of sidebands at higher frequencies extending from about 0.6 to 1.2 kHz (~1.7 to 0.8 ms), approximately the time domains represented by the complex hemisyllable structures. Macrosyllable and syllable repetition rates lie in the general ranges of 80-135 and 160-270 Hz, while chirp repetition rates (Table 2) lie between 0.5 to 2.4 Hz. These amplitude modulations evidently span much of the observed sideband frequency ranges.

1C. Short Song

Einasleigh River crossing (35km W. of Mt Surprise), and 11.7km SE of 'The Lynd' Highway Junction (Fig. 16a-e; Fig. 24a, b): The overall chirp structures of these songs differ in detail from the calling songs in the general paucity, usually absence, of precursor clicks, together with the short and erratic timings of the chirp sequence emissions. As noted, these songs were observed in very low density populations. Echeme structures comprise coalesced macrosyllables whose lengths tend to be slightly longer than observed in the calling songs, as are syllable lengths (Table 2).

The structures of the macrosyllables, syllables and hemisyllables are closely comparable to those in calling songs, again with two syllables per macrosyllable. Time expanded waveform plots (not shown) again indicate, as previously, that higher amplitude hemisyllable phases tend to have relatively higher frequencies while the low amplitude phases have both lower and higher frequencies. Rapid temporal frequency changes are characteristic, as in the calling song.

Amplitude spectra (Fig. 24a, b) show both similarities and differences from the calling songs (Fig. 23). The dominant frequencies derived from the spectra lie between 14.0 to 14.6 kHz, slightly higher than the calling songs, but the

most significant differences are seen in the wider frequency range of the stronger frequency peaks, which extend to a low of 4.9 kHz ('Lynd' junction. song) and as high as 17.4-17.5 kHz. Such wide frequency ranges would seem to enhance signal transfer relative to the calling song, perhaps a response to the low densities of these particular cicada populations. The peaks are relatively broad due to the abundant sideband line spectra. The measured sidebands, tabulated within each spectrum (Fig. 24a, b), are comparable to those measured in the calling song spectra (Fig. 23), consistent with the similar amplitude modulations and syllable structures (Table 2).

1D. Alarm (Stress) Song

58km SE of Mt Surprise and Flagstaff Hill, Bowen (Figs 16d; 21, 22a, b): Recordings at both localities were made at a time when the insects were relatively newly emerged and abundant. The song is an aurally monotonous 'buzz', lasting at least five minutes without break. It consists of randomly arranged clicks (single macrosyllables) and short echemes comprising the coalescence of between 2-5 macrosyllables (Figs 16d; 22a, b). The individual macrosyllables comprise two syllables, each with initial hemisyllable doublets. A 'doublet interval' is defined as the interval between the initial peaks in each doublet (Fig. 21c, d). These doublets are thought to represent the alternate (delayed) buckling of each timbal, with time delays of ~0.5-0.7 ms. Nevertheless, the time expanded envelope curves of the two songs (Fig. 21c, d) do differ with respect to the presence of one or two strong peaks at the end of each macrosyllable, these differences consistent throughout each of the respective recorded songs. Macrosyllable lengths range, for the data sets from 58km SE of Mt Surprise and Flagstaff Hill, Bowen, respectively, between 9.1-9.9 ms and 10.6-11.0 ms (clicks) and 8.8-9.8 ms and 10.7-11.4 ms (short echemes), similar to the values found for the calling songs, and also as observed for the syllables and hemisyllables between the two song types. The data suggest no significant compression of syllables during macrosyllable coalescence into the short echemes, while the macrosyllables in the echemes show comparable syllable-hemisyllable structures as observed in the single click macrosyllables.

The detailed waveform plot shown (Fig. 21b) illustrates the relatively high frequencies within both the higher and lower amplitude hemisyllable phases, between 10870-16305 Hz. Frequency changes, between this frequency range, occur

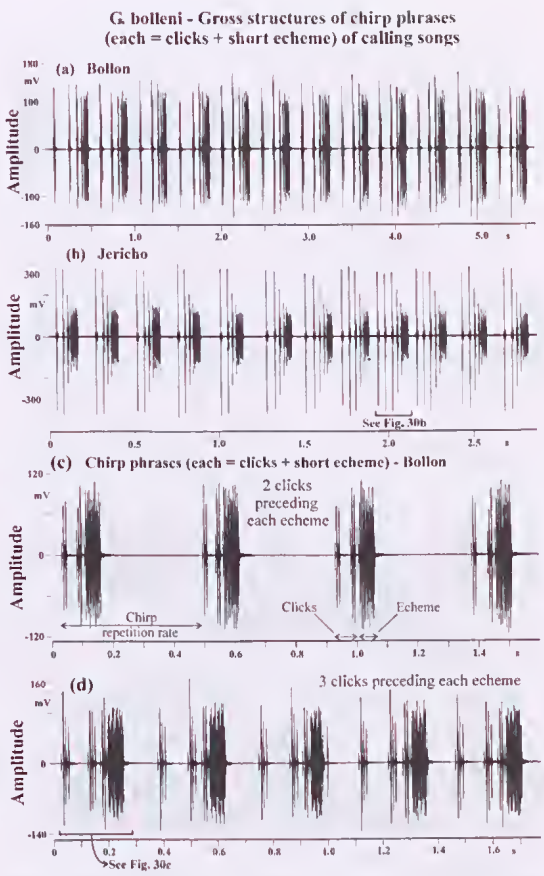

FIG. 29. *Graminitigrina bolloni* sp. nov. (a), waveform plot of calling song from Bollon, S. Queensland, showing repetitive chirp phrases, each comprising a series of initial clicks followed by a short echeme;(b), A comparable plot of a song from near Jericho, central Queensland, showing the repetitive chirp phrases. Note the more sharply defined clicks and lower amplitude short echemes; (c, d), more detailed waveform plots from Bollon showing two (c) and three (d) clicks preceding each echeme, illustrating the variable structure of the chirp phrases. The number of pre-echeme clicks varies between two and seven. The chirp repetition length (rate s^{-1}) definition is also shown in (c). (a), (c), (d), unfiltered container recordings; (b), parabola field recording (L.W. Popple), filtered (IIR) to 2 kHz.

on time domain scales of between 0.2-3 ms. The amplitude spectra of alarm songs from two localities (Fig. 24c, d) are more symmetrical (compared to the calling songs; Fig. 23), with significantly less clearly defined satellite higher or lower frequency peaks than seen in the calling and short song spectra. Complex sidebands are

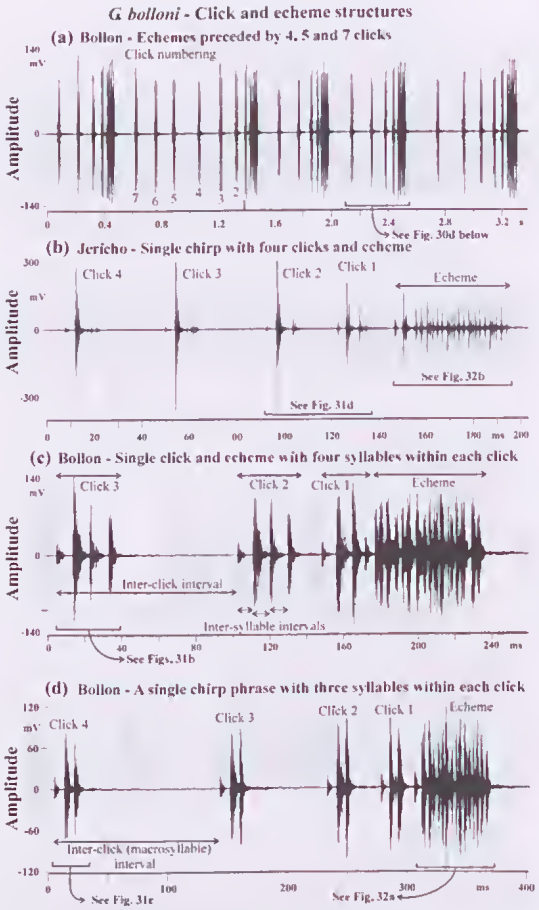

FIG. 30. *Graminitigrina bolloni* sp. nov. Calling song waveform plots; (a), chirp phrases with 4, 5 and 7 clicks preceding the echemes (Bollon song). The reference numbering system used to describe the individual clicks is shown; (b), expanded waveform plot of a single chirp with 4 preceding clicks followed by the short echeme, from near Jericho, central Queensland. Compare the clicks with those from the Bollon songs below and in Fig. 31a; (c), time expanded waveform plot of a 3 click chirp phrase showing in more detail the structure of the individual clicks, each consisting of four syllables, and the following short echeme (see Fig. 29d for location of the plot); (d), corresponding waveform plot of a 4 click chirp phrase, each click with three syllables. (a), (b), (d), unfiltered container recordings from Bollon; (b), parabola field recording, filtered (IIR) to 2 kHz (L.W. Popple).

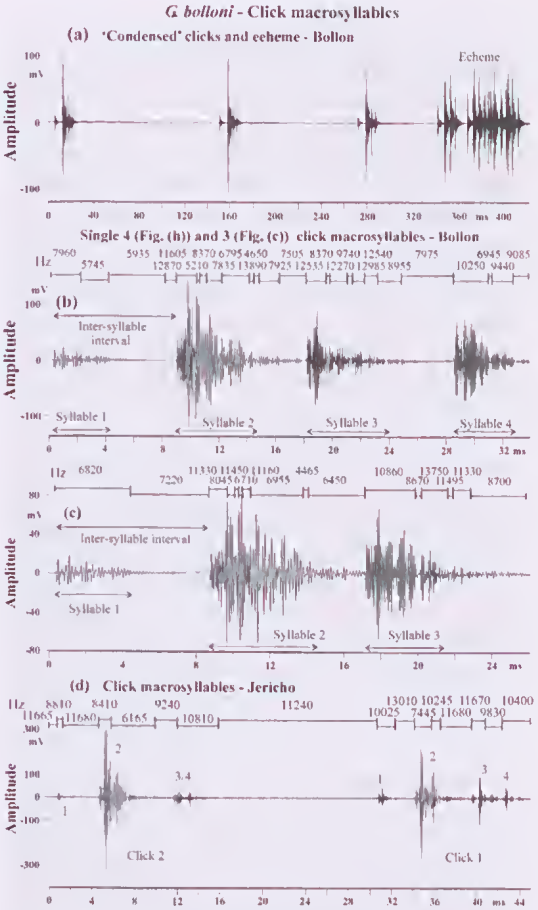

FIG. 31. *Graminitigrina bolloni* sp. nov. Calling song waveform plots; (a), expanded waveform plot of a single chirp phrase from a Bollon song illustrating a less common condensed (compressed) click structure, comparable to those of the Jericho songs; (b), higher resolution time expanded waveform plot of a single 4 syllable click (see Fig. 30c) of a Bollon song showing the measured sequential frequency changes accompanying click emission (tabulated above the plot) and the detailed higher frequency pulse structures within the syllables; (c), higher resolution time expanded waveform plot (Bollon) of a 3 syllable click (see fig. 30d) showing the measured sequential changes in frequency accompanying click emission (tabulated above the plot) and the detailed higher frequency pulse structures within the syllables; (d), expanded waveform plot of clicks 1 and 2 within a chirp phrase from the Jericho song (see Fig.30b), showing the gross frequency changes through the click syllables (tabulated above plot). Numbers 1-4 refer to the syllable reference numbering used. (a-c), unfiltered container recordings; (d), parabola field recording, filtered (IIR) to 2 kHz (L.W. Popple).

nevertheless clearly evident. The inferred dominant frequencies overlap those of the calling songs.

1E. Ratchet Song

Bowen locality. This comprises (Figs 15a, b; 22c, d) a regular sequence of single clicks (macrosyllables) emitted at a relatively constant repetition rate within a given song sequence, this being 27 Hz (37±6 ms) in the example shown. Interestingly, the click repetition rates are very similar to those for the ratchet song of *G. triodiae* (see below). Each macrosyllable (e.g. Fig. 22d) has a structure that is comparable to those of the single click macrosyllables of the calling songs (Fig. 19c, d) and stress songs (Fig. 21b-d). Each consists of two coalesced syllables with doublet intervals, as well as macrosyllable, syllable and hemisyllable properties close to those of the stress songs (Table 2).

The amplitude spectra (not shown) exhibit a blurring of the distinct frequency maxima seen in the calling and stress songs, with a broader continuity of emitted frequencies between 9 to 16 kHz and dominant frequency of 12.3 kHz, in many respects similar to the alarm song (Fig. 24c, d), but not quite as smoothly continuous in their frequency distribution. The amplitude spectra exhibit a clearly dominant sideband corresponding to the click repetition rate.

2. *G. karumbae*

2A. Calling song

Karumba and Heathlands localities. (Figs 25-28; Table 3). This song is superficially similar to that of *G. bowensis*, consisting of repeated chirp phrases (Fig. 25a) with no extended echeme phase observed. A ratchet song is emitted in the field (but has not been electronically recorded) at the end of a given song phase, followed by flight to new song post, as described for *G. bowensis*. Each chirp phrase consists of a sequence of clicks which merge into the short chirp echeme (Figs 25b, c; 26a, b). Click numbers vary between 2-13, similar to *G. bowensis*. Chirp lengths vary between 0.85-1.5 s, with repetition rates of 0.33-0.66 s^{-1}, both parameters differing from *G. bowensis*. The repetition rates progressively increase during emission. It is in the detailed chirp structures and frequencies, however, that the songs of *G. karumbae* and *G. bowensis* differ so markedly.

(i) Clicks. Time expanded envelope and waveform curves of individual click macrosyllables

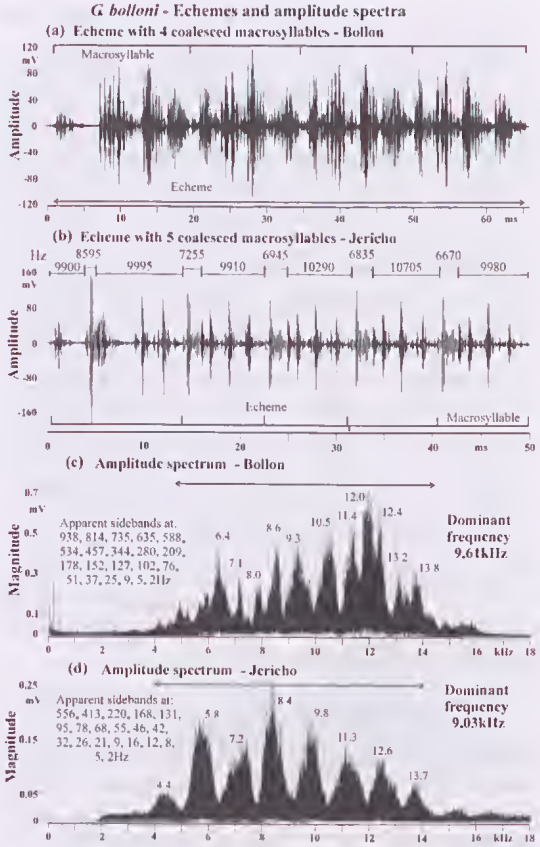

FIG. 32. *Graminitigrina bolloni* sp. nov. Higher resolution time expanded waveform plots of calling songs of; (a), the short echeme from a single chirp phrase (see Fig. 30d) from a Bollon song, comprised of 4 coalesced macrosyllables (their limits shown by the bars); (b), short echeme from chirp phrase of the Jericho song (see Fig. 30b) showing five coalesced macrosyllables (limits marked by the bars). Gross frequency changes occurring through the echeme emission are illustrated, in particular noting the lower frequencies occurring within the initial syllables of each macrosyllable, these frequencies reducing progressively during echeme progression; (c), (d), amplitude spectra of the calling songs from Bollon, and Jericho, respectively. Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. Horizontal bars mark the higher amplitude segments used to estimate the dominant frequencies of each song. (a), (c), unfiltered container recordings; (b), (d), parabola field recording, filtered (IIR) to 2 kHz (L.W. Popple).

(Figs 26c, d; 27) show that each macrosyllable consists of pairs of clearly developed syllables, each of which decays exponentially and is followed by small but distinct secondary peaks occurring

within the decaying peak tails (Fig. 27). These are termed here 'syllable doublets' rather than diplosyllables, in order to avoid obscuring certain similarities in syllable structures to those of the *G. bowensis* song. The detailed structures of the main syllable peaks in each doublet are very similar (e.g. Fig. 27c, d), suggesting the doublets result from alternate and abrupt contractions of each timbal (i.e. long ribs 'locked' as a single unit). The smaller secondary peaks may therefore represent the successive relaxation phase of each timbal, which if correct, occurs approximately 3 to 6 ms after the initiation of the preceding main syllable peaks. Mean spacing between each set of doublet syllables (excluding tails) are 9.0 ms (Karumba) and 12.5 ms (Heathlands), these differing markedly from the equivalent doublets in the *G. bowensis* songs (3.0-5.2 ms; Tables 2 and 3). The spacings between the sets of doublets reduce to 4-8 ms in proximity to the following short echeme. Macrosyllable lengths are 11.5-14.2 ms (Karumba) and 18.0-21.7 ms (Heathlands), which compare with 8.9-14.4 ms for *G. bowensis* songs (Tables 2, 3).

Pulse measurements resolved in the expanded waveform plots (Figs 27c, d) indicate frequencies of between 5420-10685 Hz (Heathlands) and 4715-12605 Hz (Karumba), clearly lower than observed for *G. bowensis* songs. Rapid frequency oscillations, however, again occur on time scales between 0.1-6 ms. The highest amplitude syllable segments are generally characterised by the higher frequencies.

(ii) Short echemes. As shown in Figs 25b, c; 26a, b; 28b, the chirps merge, with compression of the macrosyllables, into the following echeme which comprises sequences of coalesced macrosyllables. Mean macrosyllable lengths are 11.5 (Karumba) and 15.2 ms (Heathlands), longer than in the corresponding *G. bowensis* short echeme phrases, but shorter than observed in the associated clicks.

Although the macrosyllables are readily discernable within the echemes (Fig. 28a, b), detailed syllable structures are more complex than those in the click macrosyllables. For example, the well defined click syllable doublets (e.g. Fig. 27c, d) merge into echeme macrosyllables, each with initially 5-6 high amplitude pulse phrases (Fig. 28b), but later in the echeme, these tend to further coalesce and blur individual syllable identities (e.g. Fig. 28a). A possible explanation is increasing frequency of timbal contractions during echeme emission, the individual timbals becoming less rigid, allowing sequential (rather than locked) buckling of the ribs. Detailed time expanded waveform plots (not shown) of single macrosyllables from within echemes exhibit rapid alternation of higher and lower frequency domains comparable to those seen in the click phases (Fig. 27c, d).

(iii) Song frequencies. Amplitude spectra (e.g. Fig. 28c, d) exhibit a complex series of broad peaks, the strongest peaks defining a frequency window between 5.3 to 12.5 kHz (four separate insects). These frequencies are consistent with those measured on waveform plots (e.g. Fig. 27c, d), the estimated dominant frequencies ranging between 8.5-9.1 kHz (Karumba) and 7.85 kHz (Heathlands). Amplitude spectra of the click phrases alone (not shown) exhibit a distinct enhancement of both the lower and higher frequency peaks. Most significantly, the *G. karumbae* frequencies are markedly lower than those observed for *G. bowensis* calling songs.

3. *G. bolloni*

3A. Calling Song

Bollon locality. (Figs 29-32; Table 4) These typically start with a short buzz (not recorded), followed by a characteristic rapid, sharp chirping song (Fig. 29a), aurally resembling a rattling sound, emitted whilst sitting in grass. This is followed by flight to a new singing position accompanied by a 'ratchet song' (not recorded), thus exhibiting the classic "sing and fly" behaviour. The chirping song consists of short, rapidly repeated chirp phrases, each consisting of a set of short clicks followed by a short echeme of 54-90 ms (Figs 29c, d; 30a). The number of clicks varies from 2 to 7, most usually between 2 to 5. The repetition rates of the chirp phrases vary according to the number of preceding clicks and range from 1.8 s^{-1} (4 clicks) up to 3.3 s^{-1} (2 clicks; Table 4). The following descriptions deal with the structures and frequencies of the click and echeme phrases separately.

(i) Clicks. (Figs 29c, d; 30a-d; Table 4) These occur as sets of syllables, grouped into macrosyllables, which most commonly comprise sets of either triple (Figs 30d, 31c) or quadruple (Figs 30c, 31b) syllables. The sets of triplet syllables occur where >3 clicks precede each echeme, while the macrosyllables with quadruplet syllables occur where ≤3 clicks precede each echeme; in the latter cases, the final macrosyllable reverts to the triplet syllable arrangement. Click repetition rates

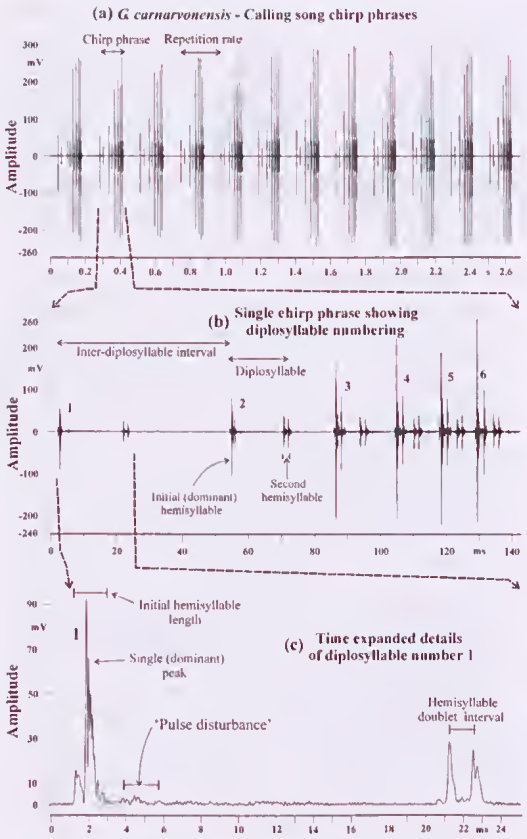

FIG. 33. *Graminitigrina carnarvonensis* sp. nov. (a), waveform plot of 12 phrases (chirps) from a calling song, each comprising 12 clicks, each pair of clicks here termed diplosyllables. Definitions of the chirp lengths and repetition lengths (rates s^{-1}) are shown; (b), time expanded diplosyllables from one phrase showing alternation of high and low amplitude hemisyllables, and numbering system used to reference individual diplosyllables. This plot also shows that the low amplitude hemisyllables are all doublets, as are most of the high amplitude hemisyllables. The high amplitude hemisyllable in diplosyllables 1 is a single syllable; (c), higher resolution envelope curve showing time expanded detail of diplosyllable 1 and the 'pulse disturbance' following the emission of the initial hemisyllable. The definition of the hemisyllable doublet intervals is shown. Based on field recording (open net cage), with parabola, from Mt Moffat Section of Carnarvon National Park (4.3km N. of entrance) filtered (IIR) to 0.2 kHz.

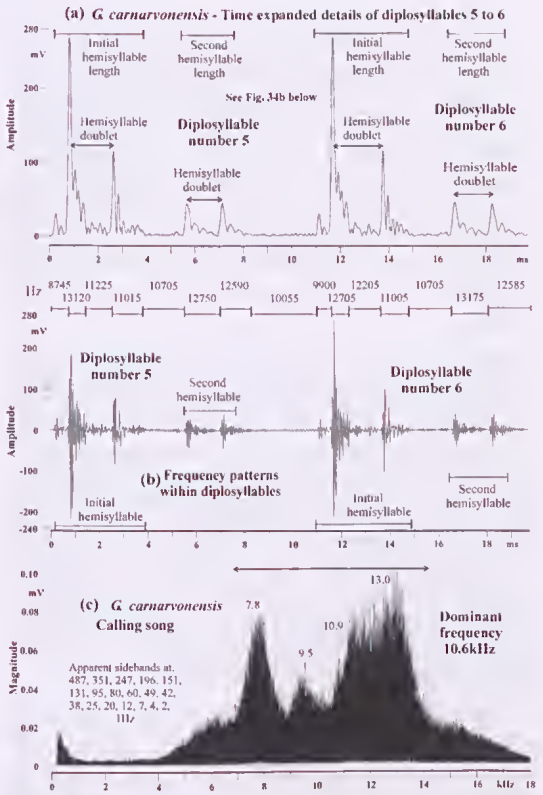

FIG. 34. *Graminitigrina carnarvonensis* sp. nov. Calling song; (a), higher resolution time expanded envelope curve showing detailed structures of diplosyllables 5 and 6, and definitions of hemisyllable doublets and lengths; (b), corresponding waveform plot showing details of the higher frequency carrier pulses, together with the gross sequential changes of frequency occurring during each hemisyllable emission (based on detailed pulse measurements in this plot); (c), amplitude spectrum of the calling song, based on analyses of an extended set (29 seconds) of sequential chirp phrases. Frequencies of the main peaks are labeled, and the apparent sidebands, measured from the spectra, are tabulated. The horizontal bar marks the higher amplitude segment used to estimate the dominant frequency of the song. Recording details as in Fig. 33.

increase towards each following short echeme. For the earlier click macrosyllables in a sequence (click numbers >3; see Fig. 30a for the numbering sequence used for the clicks), excluding the final 3 before the short echeme, the repetition rate ranges between 8.1-5.2 Hz (mean 6.4 Hz), equivalent to 124-191 ms. Between click numbers 3 and 2, the rate increases to 11.6-8.9 Hz (86-113 ms), which further increases to 23-15 Hz (43-67 ms) between click numbers 1 and 2, and to 43-26 Hz (23-38 ms) between the final click (number 1) and the start of the following short echeme. The click macrosyllable lengths range between 19.9-23.7 ms (triplets) to 26.1-33.0 ms (quadruplets).

Each click macrosyllable starts with a relatively low amplitude, abruptly initiated syllable (Fig. 31b, c), the following syllables having markedly increased amplitudes. Mean syllable lengths vary between 4.4-6.0 ms, the shortest being the initial syllable and also the final syllable in the quadruplet macrosyllables. Mean syllable repetition rates range between 8.4-10 ms (119-100 Hz). More detailed time expanded plots of the syllables suggest the probable presence of discrete hemisyllables with lengths varying between 0.9-1.2ms.

Measurements of pulses resolved within the time expanded waveform plots of the triplet (Fig. 31c) and quadruplet (Fig. 31b) click macrosyllables show marked and sharply defined variations of frequencies between approximately 6-14 kHz. The higher frequencies occur consistently within the initial segments of syllables 2, 3 and 4, but also in very short bursts (~1 ms) in the decaying phase of especially syllable 3. Syllable 1 consistently exhibits lower frequencies of <8 kHz. Syllables 2-4 show an alternation of higher and lower frequencies on time scales as short as 0.3 ms.

Certain click macrosyllable structures are relatively atypical, comprising effectively condensed short syllables (compressed syllables), shown by clicks 2-4 in Fig. 31a. The final click (number 1) in the illustrated sequence comprises a normal macrosyllable structure with four distinct syllables. Each click macrosyllable is nevertheless initiated by a sharp, low amplitude syllable, as in the normal clicks. Macrosyllable lengths range between 14-17 ms in these compressed clicks, in fact slightly longer than those of the normal click macrosyllables.

(ii) Short Echemes.-(Fig. 30c, d) These represent the coalescence of multiple macrosyllables, which individually comprise the clicks as described above. Each macrosyllable in the short echemes can be resolved into four distinct syllables, each with poorly resolved component hemisyllables. The echemes typically comprise between 3-5, less often to 8, macrosyllables. Syllable lengths range between 2.4-6.0 ms (mean 3.8 ms), tending to be slightly shorter than those measured in the click macrosyllables, indicating syllable compression. The initial macrosyllable in each echeme is the longest. Hemisyllable lengths, when resolvable, range between 0.2-1.0 ms, also shorter than those in the clicks. Pulse measurements in time expanded waveform plots indicate rapid frequency changes within the macrosyllables (not shown), as also seen in the click macrosyllables. The measured frequencies determined by the pulse counts ranged between approximately 6 to 14 kHz, also consistent with the click macrosyllable data (above). These frequency changes are short and abrupt, occurring on time scales of 0.2-1.1 ms, presumably resulting from abdominal movements during singing and the corresponding changes in sound radiation and transmission mechanisms.

(iii) Song frequencies. (Fig. 32c) The amplitude spectra of multiple chirp phrases are remarkably complex, with multiple strong frequency peaks. In the spectrum shown (Fig. 32c), the highest amplitude peak occurs at 12 kHz, but strong ancillary peaks occur at 6.4, 8.6, 9.3, 10.5, 11.4 and 12.4 kHz, with further significant peaks at 5.0, 6.0, 7.1, 8.0, 13.2, 13.8, and 14.9 kHz. The highest amplitude peaks vary between 10-12 kHz in the spectra from different insects, although the multiple frequency peaks present exhibit comparable frequencies. The mean dominant frequency is estimated to be 9.6 kHz (Table 4) from recordings of four separate insects. A conspicuous additional feature is the array of line spectra producing the broadening of the frequency peaks. Measurements of the line spectra frequencies suggest sidebands extending from 1132 to ~1 Hz (those <1 kHz tabulated in Fig. 32c). The amplitude modulations defined by the syllable and hemisyllable structures (see above) have the potential to account for sidebands in the range between ~125 Hz to ~1.1 kHz, respectively. The measured sidebands of 1042 and 1132 Hz could thus represent the lower frequency components of the hemisyllable modulation patterns. Repetition rates of the chirp phrases (1.8-3.3 Hz), clicks (5-43 Hz), and inter-syllable intervals (7.3-10.2 ms; 98-137 Hz) may account for the observed lower frequency sidebands. The wide range of the amplitude modulations certainly contributes to the complexity of the line spectra. It is possible that some of the line spectra with apparent frequencies between about 300-1000 Hz may represent multiples of the lower frequency sidebands, an artifact of the measurement procedures.

The wide range and widths of the frequency peaks observed in the spectra may be attributable to the existence of different sound radiating structures, each with different properties. This seems to be supported by the rapidly changing frequencies seen in the waveform plots, in which higher frequencies occur in the initial, higher amplitude phases within the syllable (see above). Abdominal movements are suggested

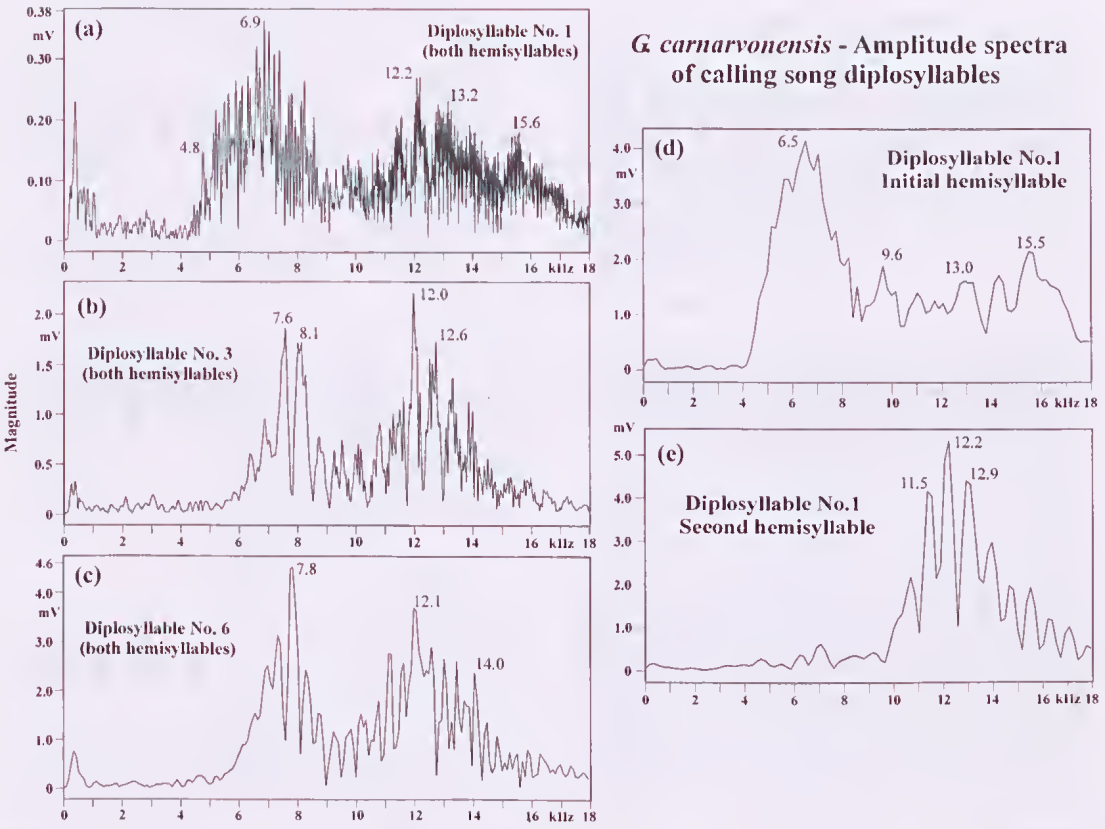

FIG. 35. *Graminitigrina carnarvonensis* sp. nov. Amplitude spectra of, (a-e), individual sets of diplosyllables (numbers 1, 3, and 6) from within a calling song chirp; (d-e), the initial and second hemisyllables within diplosyllable number 1 (see (a)). Frequencies of the main peaks are labeled. Recording details as in Fig. 33.

to modify/activate/deactivate the various sound transmitting organs, which may account for the rapidity of alternation of frequency changes, on the observed time scales as short as 0.2 ms.

Jericho locality. (Figs 29-32; Table 4) The overall temporal structures of the Bollon and Jericho songs are very similar, the latter also comprising a repetitive series of sharp chirp phrases. Each chirp again consists of 3 to 4 short clicks followed by a short echeme (Fig. 29b), although the chirp repetition rate is notably faster than the Bollon songs (Table 4). One significant difference between the two sets of songs is seen in the click structures (compare Figs 30b-d; 31b-d), in which the Jericho clicks are more sharply defined. Each click initiates with a low amplitude syllable, followed by a high amplitude second syllable and low amplitude syllables 3 and/or 4 (Figs 30b, 31d), the latter two syllables often not clearly resolved. Only in click number 1 do syllables 3 and 4 show clear separation and development. Although differing from the normal Bollon click structures, it has been noted above that compressed click structures are observed in the Bollon songs, although much less frequently (Fig. 31a); these are nevertheless similar to the Jericho click structures. The distinctive Jericho click structures are reflected in shorter echeme macrosyllable lengths, which exhibit more sharply defined and separated syllables (Figs 30b, 32b). The echemes are inferred to result through coalescence of 4 to 5 click macrosyllables, each of which comprises four syllables.

The differing, more compressed click and echeme structures of the Jericho songs are further reflected in shorter inter-click intervals and click and echeme lengths; and in shorter total click lengths, inter-syllable intervals and syllable macrosyllable lengths (Table 4). The amplitude spectra (e.g. Fig. 32d) exhibit very clearly defined, broad and regularly spaced frequency peaks, centered near 4.4, 5.8, 7.2, 8.4, 9.8, 11.3, 12.6 and 13.7 kHz. The

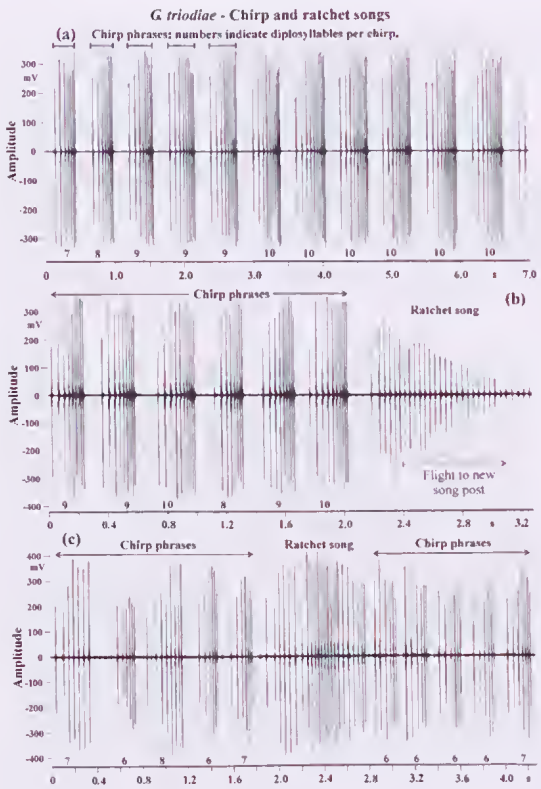

FIG. 36. *Graminitigrina triodiae* sp. nov. Waveform plots of; (a), multiple chirps within calling song, the individual chirps comprising between 7 to 10 diplosyllables; (b), a sequence of chirp phrases (each with 8 to 10 diplosyllables) followed by the ratchet song emitted immediately prior to, and accompanying flight; (c), ratchet song emitted within the normal calling song chirp sequences. Parabola field recordings, filtered (IIR) to 1 kHz, Burra Range section of White Mountain National Park.

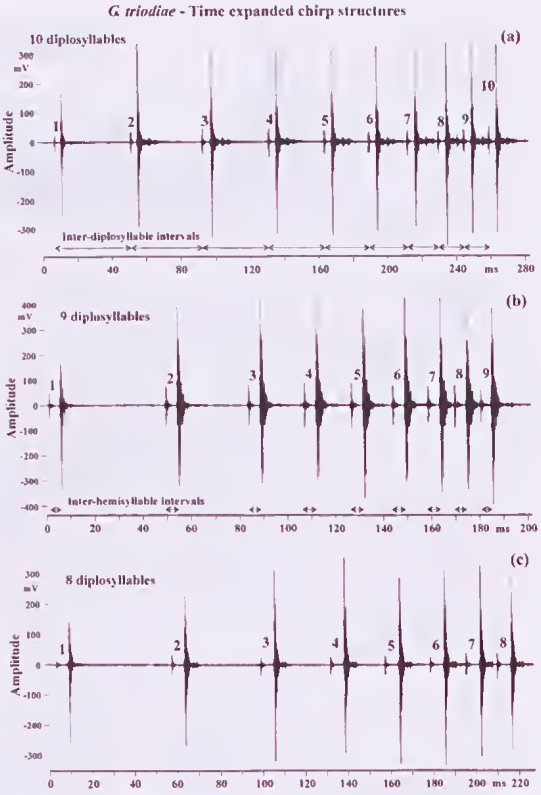

FIG. 37. *Graminitigrina triodiae* sp. nov. Time expanded waveform plots of individual chirp phrases within calling song showing details of diplosyllable structures, and the numbering system used. Number of diplosyllables per chirp vary between (a), 10; (b), 9; (c), 8. Recording details as in Fig. 36.

separations range between 1.1 to 1.5 kHz, the mean separation being 1.3 kHz, equivalent to 0.77 ms, possibly reflecting hemisyllable structures within the echemes and clicks (although not clearly resolved in the waveform plots). Apparent sidebands are listed in Fig. 32d, showing both similarities and differences with those of the Bollon songs (Fig. 32c). These seem to reflect both the gross song similarities, but also the finer scale pulse structure differences.

4. *G. carnarvonensis*

4A. Calling Song

Mt Moffat Section of Carnarvon National Park locality. (Figs 33-35; Table 5) A cryptic and wary species as characteristic of the other *Graminitigrina* species. The song data illustrated are recordings made in an open net cage, in the field in grassland associated with open forest. The song differs substantially from the previous three *Graminitigrina* songs described, consisting of repeated chirp phrases, each consisting of sets of distinct clicks (pulses) which exhibit a distinct pattern of amplitude and temporal patterning (Fig. 33a, b); no extended echeme or ratchet phrases have been observed. The clicks occur in pairs, an initial high amplitude phase followed by a low amplitude phase. These pairs are here termed *diplosyllables*. There are normally 6

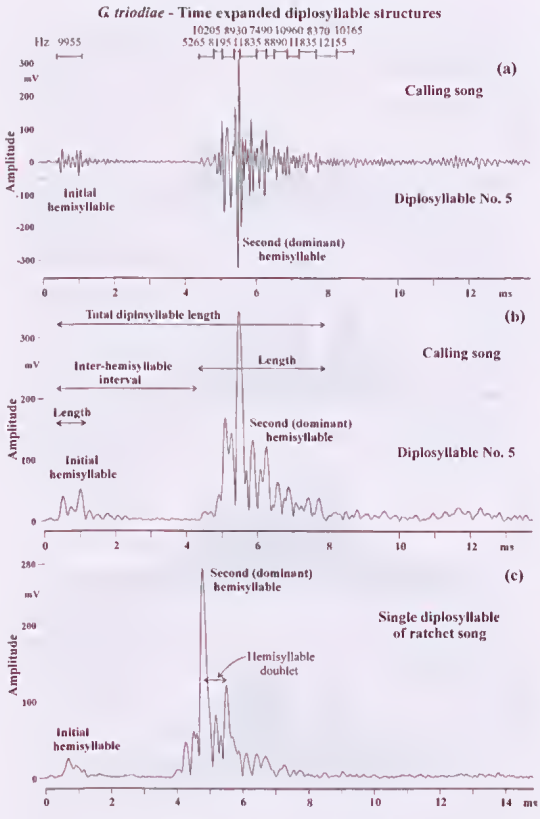

FIG. 38. *Graminitigrina triodiae* sp. nov. (a), high resolution waveform plot showing the rapid frequency changes measured (from the plot) within diplosyllable number 5 of the calling song; (b), corresponding envelope curve, showing definition of parameters and terms used in Table 6; (c), high resolution envelope curve showing details of a single diplosyllable of the ratchet song. Recording details as in Fig. 36.

sets of diplosyllables within each chirp phrase; in one recorded song, however, a small number of chirps possessed 7 sets, and an even smaller number has 5 sets of diplosyllables. The two clicks (pulses) within each diplosyllable are here termed the initial (high amplitude) and the second (low amplitude) hemisyllables, respectively (Fig. 33c). The initial hemisyllable of diplosyllable 1 (numbering shown in Fig. 33b) consists of a single dominant pulse. Diplosyllables 2 and 3 (and 4, 5 in the chirps with 7 diplosyllables) are also single hemisyllables in many recorded chirp phrases. The remaining initial hemisyllables, and all the second hemisyllables occur as clearly defined 'hemisyllable doublets' (e.g. Figs 33c; 34a, b). The initial hemisyllables of diplosyllables 3 to 6 also have higher amplitudes than those of diplosyllables 1 and 2. The emission rate of the diplosyllables progressively increases during the emission of each phrase (Fig. 33b, Table 5). Chirp phrase lengths range between 120-190 ms, with mean chirp repetition rates of 3.8 Hz (261 ms), these varying between 209-366 ms (2.7-4.8 Hz). Just as the inter-diplosyllable intervals decrease during emission of each chirp phrase, the time intervals between adjacent hemisyllable pairs within each diplosyllable also decrease (Fig. 33b; Table 5).

(i) Diplosyllable and hemisyllable structures. A characteristic feature of the initial hemisyllables of all diplosyllables is the presence of a distinct preliminary small pulse emitted approximately 0.6 ms (0.37-0.82 ms) prior to the leading main peak of each hemisyllable (Figs 33b, c; 34a). Small 'pulse disturbances' (in fact, two sets may be present in diplosyllable 3) follow the emission of the single initial hemisyllables of the diplosyllables 1 (±2, ±3). These occur ~2.5-5.6 ms following the preceding initial hemisyllable (up to 9.3 ms in the cases of double ' pulse disturbances' associated with diplosyllable 3). Similar 'pulse disturbances' are not clearly identified following the initial hemisyllables of diplosyllables 4 to 6 (all hemisyllable doublets). The hemisyllables comprising single pulses have lengths (including the tail and preliminary peak) of ~1.7 to 2.0 ms (Table 5); in contrast, the corresponding doublet initial hemisyllables of diplosyllables 2 to 6 (Fig. 34a, b) have lengths between 2.0-3.0 ms, suggesting that the second peak of the doublet represents the appearance of an additional peak. The second hemisyllable doublets of all 6 diplosyllables are similar in structure. In these second hemisyllables, time intervals between the two peaks comprising each hemisyllable doublet range between 0.8-2.0 ms (diplosyllables 4 to 6), 0.9-2.0 ms (diplosyllables 1, 2) and 1.6-2.7 ms (diplosyllable 3; Table 5), each of similar magnitude.

(ii) Song frequencies. The amplitude spectrum shown (Fig. 34c) is based on analyses of a sequence of 29 seconds of continuous chirp phrases. It exhibits a complex broadband spectrum extending between approximately 6-14 kHz, with two broad main peaks centered at 7.8 and near 13 kHz, and a smaller peak at 9.5 kHz. The spectrum is bimodal. The breadth and complexity of the spectral peaks is attributed to the extensive sets of sideband line spectra (tabulated in Fig. 34c). The various chirp diplosyllables, and their varying repetition rates, chirp lengths and inter-diplosyllable intervals, result in a wide range of

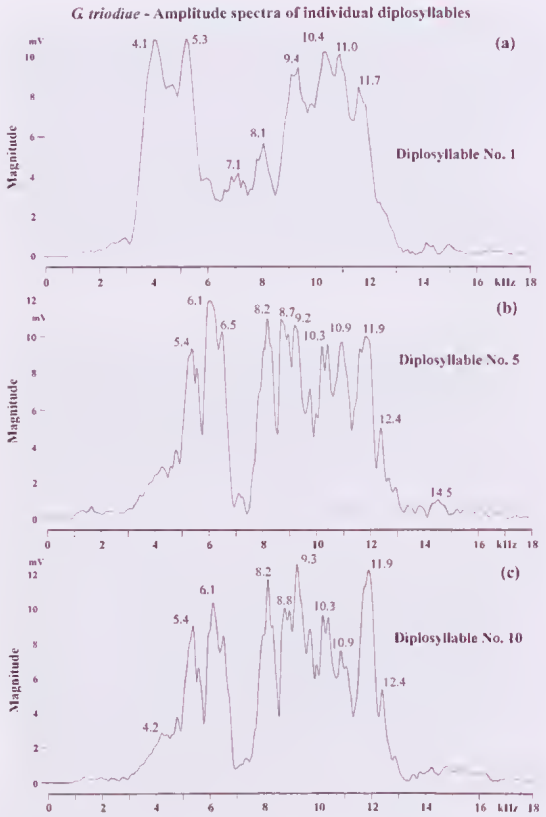

FIG. 39. *Graminitigrina triodiae* sp. nov. Amplitude spectra of individual sets of diplosyllables (numbers 1, 5 and 10) within a single calling song chirp. Frequencies of the main peaks are labeled. Recording details as in Fig. 36.

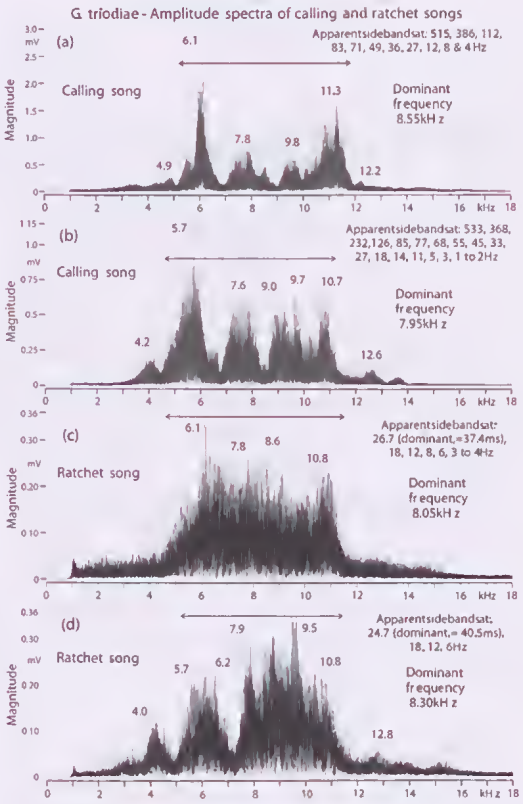

FIG. 40. *Graminitigrina triodiae* sp. nov. Amplitude spectra of, (a-b), sequences of multiple chirps (10 to 11) within calling songs from two separate insects; (c-d), multiple diplosyllables within ratchet songs from two separate insects. Frequencies of the main peaks are labeled together with the apparent sidebands measured from these spectra. Recording details as in Fig. 36.

possible amplitude modulations, listed in part in Table 5. The corresponding frequencies of these amplitude modulations range from ~2.7 to 200 Hz (Table 5) and are represented as sidebands in the amplitude spectra (e.g. Fig. 34c). Added to these are the higher frequency amplitude modulations seen in the detailed hemisyllable structures (Figs 33c, 34a; Table 5), whose numerical values differ through the changing diplosyllables comprising each chirp phrase; these modulations extend to above 450 Hz (Table 5), further emphasising the complexity of this song. The mean dominant frequency of the calling song is estimated to be 10.1 kHz (three separate insects; Table 5).

Frequencies of the carrier wave pulses measured from time expanded waveform plots (e.g. Fig. 34b) are clearly in the range demonstrated by the amplitude spectra (e.g. Figs 34c; 35a-e), ranging between 7865-13120 Hz (initial hemisyllables), and 9710-13620 Hz (second hemisyllables), suggesting that the second hemisyllables possesses slightly higher overall frequencies. The 'pulse disturbances' seen within diplosyllables 1 to 3 tend to have frequencies similar to their preceding initial hemisyllables. It is also notable that the initial small pulses occurring at the start of each of the initial hemisyllables have consistently lower frequencies compared with the following the main segments of these hemisyllables. The differing frequency structures within the various diplosyllables are further illustrated in Fig. 35a-e, which compare the amplitude spectra of diplosyllables 1, 3, and 6 from a selected single chirp phrase. The general form of the spectra are modified by the progressively reducing spacings between the initial and second hemisyllables in diplosyllables 1 to 6. Nevertheless, each

clearly shows the bimodal frequency character of the spectra. From these, it is evident that in diplosyllable 1 a relatively greater concentration of frequency peaks below about 9 kHz is present, this contrasting with the spectra of diplosyllables 3 and 6. The relative frequency distributions within the initial and second hemisyllables of diplosyllable 1 (Fig. 35d, e) show that it is actually the initial hemisyllable (high amplitude) that is characterised by the lower frequencies (~5-8 kHz), the second hemisyllable exhibiting clearly higher frequencies between approximately 11-13 kHz. The remaining diplosyllables, however, do not show such marked differences between the overall frequency structures of the two hemisyllables (Fig. 34b), although noting (as above), the short lower frequency segments at the start of each initial hemisyllable.

4B. Interpretation

The song of *G. carnarvonensis* is distinct from the three species previously described, although resembling that of *G. triodiae* (see below). The timbal structure (Fig. 11) of *G. carnarvonensis* shows four very pronounced long ribs, with ribs 1-3 clearly fused ventrally and dorsally, while rib 4 is not fused ventrally. Three short ribs are present. Several possibilities exist for relating the observed song structures to timbal morphology. These include: (a) The second hemisyllables (all doublet pulses) represent the 'clicking back' during timbal relaxation, the high amplitude initial hemisyllables representing the initial inward buckling. This explanation may be appropriate where both the high and low amplitude syllables are clearly doublets (diplosyllables 4 to 6, ±2, ±3), but seems to require that the hemisyllable doublets result from the clicking of ribs 1-3 as a 'locked' unit, followed by rib 4, in both 'inward' and 'outward' movements. The initial single 'pulse' hemisyllables could represent the inward clicks (and resulting sound radiation) under higher impedance conditions, which decrease during the emission of each chirp phrase. This may also relate to the 'pulse disturbances' seen to follow these single initial hemisyllables, and also the wider separation of the following second hemisyllable doublets. (b) A second possible interpretation is that each initial hemisyllable represents a complete 'in-out' timbal movement of the 'locked' ribs 1 to 3. The low amplitude second hemisyllable doublets may therefore represent the 'in-out' movement of long rib 4, although it is not clear how this could account for the single initial hemisyllables of diplosyllables 1, ±2, ± 3. However, unlike the initial hemisyllables of diplosyllables 4 to 6, diplosyllables 1 to 3 are followed, after approximately 2.5-5.6 ms, by a short 'pulse disturbance', which might feasibly represent the strongly damped relaxation 'click' of ribs 1-3.

5. *G. triodiae*

5A. Calling Song

Burra Range section of White Mountain National Park locality. (Figs 36, 37) The calling song has similarity to that of *G. carnarvonensis*, again consisting of repeated chirp phrases, each comprising discrete diplosyllables which most commonly vary between 7 to 10, less often 6 to 11, in number (Figs 36, 37; Table 6). Chirp phrase lengths range between approximately 148-281 ms (field recordings), and 255-436 ms (container recordings), the lengths predictably correlating with the number of diplosyllables present. Each diplosyllable comprises an initial low amplitude hemisyllable, followed by a high amplitude (dominant) second hemisyllable (Figs 37, 38), the reverse of that seen in the *G. carnarvonensis* calling song. Each chirp phrase is characterised by a progressive increase in diplosyllable emission rate from start to finish, as in *G. carnarvonensis* (Figs 36, 37; Table 6), ranging from near 18 Hz to approximately 70 to 80 Hz at the end (Table 6). Repetition rates of the chirp phrases vary between 2.2-4.3 Hz for field recordings, and are significantly slower at 1.3-1.9 Hz for container recordings; the differences are attributed to the observation that all specimens recorded in the field were singing in direct sunshine.

As observed in some other *Graminitigrina* species, an additional 'ratchet' song is emitted almost invariably at the end of a calling song sequence, when the cicada is about to fly to, and during actual flight, to a new singing perch (Fig. 36b). Rarely the 'ratchet' song occurs within the calling song phase (Fig. 36c), seeming to accompany reduced diplosyllable numbers in associated chirp phrases. The 'ratchet' song is characterised by a series of discrete diplosyllables showing, within a given song, a relatively consistent repetition rate, and when at the end of a calling song, reduced amplitude accompanying the flight of the insect away from its singing post.

(i) Diplosyllable structures. The distinctive feature is the presence of the low amplitude of the initial hemisyllable, followed by the dominant (high

amplitude) second hemisyllable. Notwithstanding the increasing repetition rate of the diplosyllables in each chirp, the inter-hemisyllable intervals (Fig. 38b) are constant (mean 4.1 ms; Table 6), with no systematic variation evident within each diplosyllable. The lengths of both the initial and second hemisyllables are also relatively constant (means of 0.93 and 3.5 ms, respectively), while pulse structures with both types of hemisyllables through a given chirp phrase are very similar (e.g. Fig. 37). The consistency of these parameters indicates that each diplosyllable likely results from the same sound producing mechanism. As shown in Fig. 38a, b, the dominant second hemisyllable does not initiate instantly, but builds to a maximum over approximately 1 ms, and decays along a broadly logarithmic curve over approximately 2 to 2.5 ms. The actual point of initiation of these hemisyllables are marked by a very low amplitude 'disturbance' (shown in Fig. 38a, b).

(ii) Song frequencies. As observed in the previously described songs of *Graminitigrina* species, measurements of pulses made on detailed waveform plots (e.g. Fig. 38a) reveal rapid and marked changes of pulse frequencies (5265-12155 Hz), even within individual second hemisyllables, on time scales between 0.2-0.6 ms. Figure 38a also indicates that the frequencies extend to both lower and higher values than observed in the smaller initial hemisyllables. Comparison of detailed waveform plots of different diplosyllables from within a given chirp phrase suggests some subtle frequency differences between the initial diplosyllable (number 1; diplosyllable numbering shown in Fig. 37) and the following diplosyllables. This is shown in more detail by amplitude spectra determined on individual diplosyllables, three of which are illustrated (Fig. 39). Diplosyllable 1 exhibits a strong peak at 4.1 kHz, which is not so clearly developed in the following diplosyllables. These spectra also exhibit strong frequency bimodality, most clearly developed in diplosyllable 1, due to the reduced amplitude of frequencies between ~6-9 kHz. Diplosyllables 2 to 10 show the same amplitude spectra as those of the illustrated diplosyllables 5 and 10. This bimodality cannot, however, be simply correlated with differences in the frequencies observed in the initial and dominant second hemisyllables themselves, the spectra of which tend to extensively overlap in their frequency ranges.

Amplitude spectra of multiple (10-11) chirp phrases (Fig. 40a, b), from different insects, exhibit a complex of peaks centered at approximately 5-6.5, 7-8, 9-10, and 10.5-11.8 kHz, with minor peaks at 12-13 kHz. The breadth of the peaks reflects the multiplicity of lower frequency side bands, correlated with the complex array of amplitude modulations arising from the various diplosyllable and hemisyllable structures, listed in Table 6. The broadband character of the main array of frequency peaks is significant, and compares with the calling song spectra of both *G. bolloni* and *G. carnarvonensis*. These major frequency peaks cannot be readily related through possible higher frequency sidebands. They are thought, in line with previous interpretations made above for the other described *Graminitigrina* species, to reflect changing sound radiation patterns. This would be consistent with the observed very rapid frequency changes observed in the expanded waveform plots (e.g. Fig. 38a).

5B. Ratchet Song

This comprises a sequence of discrete diplosyllables (clicks) with constant repetition rate within a given song sequence, these varying between 22-37 Hz (mean 27.5 Hz). Each diplosyllable has a closely similar structure to those of the calling song (Fig. 38b, c) with a low amplitude initial hemisyllable and dominant second hemisyllable, whose time paramcters are also similar (Table 6). One minor difference is the existence of a distinct pulse doublet in the dominant second hemisyllable (Fig. 38c), somewhat similar to those seen in the dominant hemisyllables of *G. carnarvonensis*.

Amplitude spectra of ratchet songs (Fig. 40c, d) indicate a blurring of the clearly defined frequency peaks that are seen in the calling songs, with a consequently broader continuity of emitted frequencies, although within the same overall frequency envelope as the calling songs. The spectra are characterised by a dominant sideband which precisely corresponds, within each specific recorded ratchet song, to the click repetition rates. If the distinct frequency peaks of the calling songs are the result of changing sound radiation characteristics of the insects, resulting from rapid abdominal movements, then the more evenly distributed frequency structure of the ratchet song suggests the damping of these abdominal movements.

5C. Interpretation

The songs of *G. triodiae* has marked similarities to those of *G. carnarvonensis,* and to a lesser

extent those of *G. bolloni*. The calling song differs from that of *G. carnarvonensis* in terms of both the number of diplosyllables within each chirp phrase, and the occurrence of low amplitude initial hemisyllables followed by high amplitude second hemisyllables, the reverse of that seen in the songs of *G. carnarvonensis,* These pulse structures of *G. triodiae* represent an apparently atypical feature within Australian cicada songs. The timbal structures of *G. triodiae* also differ from those of *G. carnarvonensis* in respect to the fusion of ribs 1 to 4 both ventrally and dorsally, the very weakly developed short ribs between ribs 1 to 4, and the very robust rib 4 and the short but robust rib 5 (compare Figs 11c, 13c). As the number of diplosyllables per chirp varies between 6 to 11, their production cannot be correlated with the sequential bucking of the individual ribs of either one or both timbals. Three possible explanations are put forward to relate the observed songs to observed timbal structures.

(a) Ribs 1 to 4 may be 'locked' and therefore buckle as a single unit. If correct, this could imply that each diplosyllable represents the buckling of one timbal, with the low amplitude initial hemisyllable related to buckling of rib 5, and the second, high amplitude hemisyllable the simultaneous bucking of ribs 1 to 4 as a unit. One problem raised by this explanation is the apparent lack of a peak representing the relaxation of the ribs, unless this occurs so rapidly as to be incorporated within each of the hemisyllable emissions. It also implies that successive diplosyllables result from alternating buckling of the timbals, possibly consistent with the variable diplosyllable numbers within the chirp phrases.

(b) Ribs 1 to 3 are locked as a unit during buckling and therefore buckle independently of the more robust rib 4. The initial low amplitude hemisyllable could thus represent the initial weaker buckling of ribs 1 to 3, followed by the buckling of rib 4 producing the stronger second hemisyllables. This further suggests that each diplosyllable represents the buckling of a single timbal, with alternate buckling of the two timbals producing the sequences of syllables within each chirp phrase. Again, this explanation does not account for the lack of relaxation peaks, unless these coincide with the hemisyllables, which seems unlikely due to the changing repetition rates of the diplosyllables.

(c) A third possible explanation is that the initial weak hemisyllables represent the simultaneous inward buckling of ribs 1 to 4 (±5), followed by a more 'explosive' relaxation to give the stronger second hemisyllable within each diplosyllable. Support for this explanation is found in the unusually robust rib 4 (± rib 5) which may provide an effectively stronger resistance (stiffness) to initial buckling, but once buckled, relaxation may occur very readily and strongly. The sequence of diplosyllables within a chirp phrase would seem again to require alternate buckling of the two timbals. This explanation is preferred.

DISCUSSION

The above documentation of the calling songs show that clear differences exist between the songs of each of the five described species. These include temporal arrangements of clicks and echemes, detailed syllable/macrosyllable structures and the resulting emitted frequencies. The calling songs of *G. bowensis* and *G. karumbae* show marked similarities in their gross temporal echeme and chirp structures, but differ clearly in their detailed syllable structures and song frequencies. The calling songs of *G. carnarvonensis* and *G. triodiae* also share marked similarities, both dominated by diplosyllables arranged within phrases without associated echemes. Again, detailed syllable structures are significantly different between these two species. The *G. bolloni* calling song is clearly distinct in the temporal structuring of its clicks and short echemes from the songs of *G. bowensis* and *G. karumbae*. Excepting *G. carnarvonensis*, all species share the ratchet song which is aurally very similar between each species, especially in the click repetition rates (see Tables 2 and 6 summarising song parameters of *G. bowensis* and *G. triodiae*).

An important feature of all the *Graminitigrina* calling songs is their wide range of emitted frequencies and the complexity of their amplitude spectra (Figs 23, 28, 32, 34, 40), this being especially marked for *G. bolloni*, *G. carnarvonensis* and *G. triodiae*. This aspect is particularly relevant in the context of the small size of these cicadas, noting the general correlation between decreasing body size and increasing song frequency (e.g. Bennet-Clark and Young, 1994). The broad frequency peaks seen within the various amplitude spectra reflect the extensive ranges of sidebands that are present. These further correlate with the wide ranges of amplitude modulations defined by the respective chirp and echeme structures illustrated in the respective waveform plots. As documented by Fonseca and Popov (1994) in the similarly small Portugese cicada *T. gastrica*

Stål, such wide and complex frequency spectra reflect separate sound radiation structures, and their possible differential contributions to the click and short echeme song phases. These sound radiation structures are the timbals, tympana and abdomen, the latter most important in radiating lower frequencies. The other feature of note, documented in time expanded waveform plots of the calling songs of each *Graminitigrina* species, is the very rapid alternations of higher and lower frequency domains on time scales between ~0.1 to about 6 ms. These imply rapid and continuous body movements during singing, constantly changing the relative contributions of each sound radiating structure.

The wide range of frequencies emitted by the five described species, which effectively constitute multiple distinct frequency channels, produce marked ventriloquial effects in the field, which when combined with the cryptic colouration and very mobile behaviour of the adults, seem to provide effective defense strategies. The multiple frequency channels are also suggested to enhance the efficient transmission of songs in the dense grass in which the adults exist, the differing frequencies offsetting sound losses due to degradation by absorption, scattering, boundary reflections and refractions during sound propagation and ensuring that at least some frequency components will successfully propagate with minimum distortion. The higher frequency components also potentially facilitate sound localisation (Gerhardt and Huber, 2002).

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ADDENDUM

G. bowensis. Additional song documentation.

As listed in the paratype data for *Graminitigrina bowensis*, a series of specimens are included from Slaty Creek, approximately 25km southwest of Cloncurry, North West Queensland. This locality represents a significant extension of the known distribution of *G. bowensis* and represents an outlying and very probably isolated population. No song data were available.

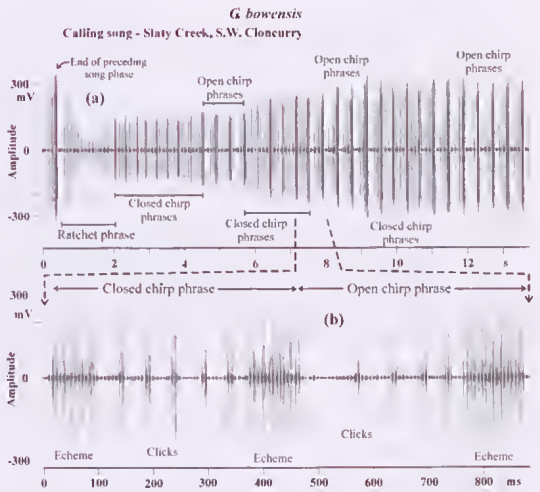

Figure A1. *Graminitigrina bowensis*. Waveform plots of calling song of the Slaty Creek population, approximately 25km southwest of Cloneurry, N.W. Queensland. (a) Three song phases recognised, comprising the ratchet, closed chirp, and open chirp phrases. The start of the plot shows the end of the preceding song phase, followed by the ratchet song, followed by the initiation of the new calling song phase at a new song post. The drop of amplitude in the ratchet song between the two song phases marks the flight between the two song posts, during which the ratchet song continues to be emitted. (b) Time expanded plot showing further details of click and short echeme structures of the closed and open chirp phrases. Based on field recordings, using a Marantz PMD660 digital recorder with Sennheiser K6/ME66 microphone.

During 15-16 January 2008, AE visited this locality and digital field recordings were made of the songs from multiple cicadas that had newly emerged. Representative waveform plots are shown (Figs A1a, b) of the calling songs. Three distinct song phases are identified, comprising two types of chirp phrases plus a ratchet phrase which is emitted at the termination, in between flight, and at the commencement of singing at a new song post. The two types of chirp phrases are here referred to as closed and open chirp phrases. The closed type consist of pairs of short chirp echemes with four, rarely five, intervening clicks (each a single macrosyllable), emitted with nearly constant repetition rates. These are not specifically recognised in the songs described from the other localities, but do show some similarity to the pre-extended echeme chirp phases of the Bowen

population. The closed echemes are characteristic of the early phase of each song sequence, being more sporadically emitted between the open chirp phrases during the main segments of the calling song. The click repetitive rates are the same as observed in the ratchet song phrases. The open chirp phases are very similar to the normal chirp phrases of the *G. bowensis* songs already described. They comprise most usually four (3-5) discrete clicks, each a single macrosyllable, which are emitted with progressively increasing repetition rates, and thereby merge into the following short chirp echemes.

For the closed chirp phrases, repetition rates range between 2.7 – 4.7 Hz, and 20-33 Hz for intervening clicks; short echeme widths are 0.06-0.12 s. For the open chirp phrases, the corresponding values are 1.6-3.3 Hz, 15-47 Hz, and 0.10-0.14 s, the latter slightly shorter than observed at other localities (Table 2). Lengths of click macrosyllables in all song phrases range between 10.0-12.6 ms. Click repetition rates in the ratchet phrase are 19-26 Hz. These parameters are similar to those observed within the calling songs of this species from the other localities, listed in Table 2. The dominant frequencies are 10.9-11.3 kHz, slightly lower than observed in the other localities. The amplitude spectra are consistently asymmetric, however, with the maxima frequencies at 12.4-13.1 kHz.

In summary, the calling songs of the Slaty Creek Graminitigrina population are concluded to be consistent with that of *G. bowensis* from the type locality, although noting the additional development of the closed chirp phrases.

A NEW SPECIES OF *OEDASPIS* LOEW AND NEW RECORDS OF OTHER FRUIT FLIES (INSECTA: DIPTERA: TEPHRITIDAE) FROM NEW CALEDONIA

D.L. HANCOCK

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The number of fruit fly species known from New Caledonia is increased to 29. *Oedaspis ouinensis* sp. nov. is described from Mt Ouin, while *Piestometopon distinctum* (Permkam & Hancock) and *Ornithoschema mallochi* Hardy are newly recorded from the territory. The presence of *Bactrocera trilineola* Drew in the Loyalty Islands is confirmed. ❐ *Fruit flies, New Caledonia, new records, eastern Australia.*

David L. Hancock, PO Box 2464, Cairns, Qld 4870; 19 February 2007.

Norrbom & Hancock (2004) reviewed the fruit fly fauna of New Caledonia and recorded 25 species. The pest species *Bactrocera trilineola* Drew was added to the list by Mille (in press). Further collecting, by staff of the Queensland Museum, Brisbane (QM), has provided additional records of ten species, including two new records for the territory and one new species.

A feature of this fauna, strengthened by the present records, is its apparent relationship with that of eastern Australia, particularly Queensland. Several species are shared, not all of which can be attributed to human introduction, while others are closely related to northeastern Australian species, including the new species of *Oedaspis* Loew described below.

SYSTEMATICS

Subfamily DACINAE
Tribe Dacini
Bactrocera (Bactrocera) psidii (Froggatt, 1899)

MATERIAL. NEW CALEDONIA: 1♀, Nehoue campground, 20°25'S, 164°13'E, 29.iv.2005, G.B. Monteith, MV light, 10m (in QM).

COMMENTS. This species appears to be widespread in New Caledonia.

Bactrocera (Bactrocera) trilineola Drew, 1989

MATERIAL. NEW CALEDONIA: 3♂♂, 1♀, Maré, 5.vii.1993 (1♂), 2.viii.1993 (2♂♂), 16.viii.1993 (♀), ex cue-lure trap (in Station Recherches Frutières de Pocquereux [SRFP], La Foa, New Caledonia).

COMMENTS. This species is widespread in Vanuatu. In New Caledonia it is known only from Maré and Lifou in the Loyalty Islands (C. Mille, pers. comm.). The above specimens were previously misidentified as *B. frauenfeldi* (Schiner).

Subfamily PHYTALMIINAE
Tribe Acanthonevrini
Austronevra irwini Norrbom & Hancock, 2004

MATERIAL. NEW CALEDONIA: 1♀, Col d'Amieu, west slope, 21°37'S, 165°49'E, 480m, 7.i.2005, G.B. Monteith, MV light, rainforest (QM).

COMMENTS. This species is known only from New Caledonia. Elsewhere, the genus *Austronevra* Permkam & Hancock is known only from rainforests of northeastern Queensland, where two additional species occur (Permkam & Hancock, 1995).

Dirioxa pornia (Walker, 1849)

MATERIAL. NEW CALEDONIA: 2♀♀, Foret Nord, site 2.malaise, 22°19'S, 166°55'E, 200m, 2-22.xii.2004, [C.] Burwell, [S.] Wright, rainforest; 2♀♀, same data except 22.xii.2004-9.i.2005; 1♀, Nehoue campground, 20°25'S, 164°13'E, 29.iv.2005, G.B. Monteith, MV light, 10m (all QM).

COMMENTS. This fruit-infesting species appears to have been introduced into New Caledonia from eastern Australia, where it is widespread.

Subfamily TEPHRITINAE
Tribe Dithrycini
Subtribe Platensinina
Oedaspis ouinensis sp. nov. (Fig. 1A)

ETYMOLOGY. Named after the type locality, Mt Ouin.

MATERIAL. HOLOTYPE ♂: NEW CALEDONIA: 11152, 22°01'S, 166°28'E, Mt Ouin, 1100m, 9.xi.2002, S. Wright, beating (in Muséum National d'Histoire Naturelle [MNHN], Paris).

DESCRIPTION. Male. Length of body 5mm, of wing 5mm. Head higher than long, with antennae situated at upper quarter; yellow-brown, tending red-brown on frons and occiput; face gently concave; antennae shorter than face, with third segment red-brown, twice as long as wide, apically rounded with a slight dorsoapical projection; ptilinum extruded in holotype. Setae well developed and black except upper orbitals, outer verticals, postocellars and row of postoculars thin and yellow; 5 pairs frontals; 2 pairs orbitals; 1 pair ocellars; 1 pair inner verticals.

Thorax red-brown except for a black pattern over posterior part of scutum, extending anterolaterally to suture and medially to anterior margin as narrowing vittae and over disc of scutellum; covered with fine, pale microtrichia and short, recumbent yellow setulae. Setae well developed and dark brown to black: 1 pair dorsocentrals situated slightly closer to suture than to line of anterior supra-alars; anepisternum with 1 thick upper and 3 thinner lower setae, plus 2 thin inner setae; 2 pairs scutellars, the apical pair about three-quarters length of basals and crossed near apex. Scutellum almost flat, disc slightly convex. Legs yellow-brown; hind femur without a preapical dorsal seta.

Wing pattern (Fig. 1A) largely brown, tending yellowish basally and in central portion, with medial part of cell c and behind it to cell bcu diffusely paler and the following hyaline markings across apical two-thirds of wing: a narrow, rectangular band across cell r_1 at apex of vein R_1; four narrow, transverse bands extending to hind wing margin, 2 in cell cu_1, the subbasal one slightly oblique (the anterior end more distal) and extending from vein R_{4+5} and the subapical one extending from vein M, and 2 bands ending in cell m, slightly oblique (with anterior ends more proximal), the subbasal band extending from cell r_{2+3} and the subapical one from middle of cell r_{4+5}; all hyaline bands narrower than the dark bands between them; apex of wing brown with no hyaline marginal marking, the infuscated area is largely brown, except yellowish anteromedially in the three middle brown bands and basal parts of cells r_{2+3} and dm; anal lobe and patterned areas of cells cu_1 and m largely brown; pterostigma (cell sc) dark brown. Setae on vein R_1 uninterrupted opposite apex of vein Sc; vein R_{4+5} bare; R-M crossvein situated at apical three-quarters of cell dm, about its own length from DM-Cu crossvein; cell bcu apically produced and acute.

Abdomen reddish-brown, tending yellowish on terga I+II; terga III to V mostly blackish-brown, with lateral and posterior margins narrowly yellow-brown; with brownish microtrichia and short, fine dark setulae. Genitalia red-brown; distiphallus with the glans elongate, slightly swollen and with a membranous apical extension, similar in appearance to that of *O. mouldsi* (see Hardy & Drew 1996: fig. 104).

Female unknown.

DISTRIBUTION. Known only from the type locality in New Caledonia.

COMMENTS. This species most closely resembles *Oedaspis mouldsi* Hardy & Drew, from Mt Lewis and Mt Misery in northern Queensland (Hardy & Drew, 1996) and, like that species, has the hyaline bands in the posterior part of the wing much narrower than the dark bands between them. It differs from *O. mouldsi* in having the apex of the wing entirely brown without a hyaline apical spot in cells r_{2+3} and r_{4+5}, and in the largely blackish-brown abdominal terga III-V.

Oedaspis is primarily a Palaearctic-Afrotropical genus but it is also well represented in Australia, where some 20 species are known (Hardy & Drew, 1996; Hancock, 2001). However, this new species is the first record of the genus from New Caledonia or any other Pacific Island territory. Species with known biologies form stem galls on Asteraceae and Goodeniaceae.

Tribe Tephritini

Dioxyna conflicta (Curran, 1929)

MATERIAL. NEW CALEDONIA: 1♀, Cap Ndoua, site 1, 22°23'S, 166°56'E, 28.xi.2004, S.G. Wright, sweeping, rainforest (QM).

COMMENTS. This species appears to be widespread in the South Pacific, occurring as far east as Samoa and Niue (Hancock & McGuire, 2001).

Tetreuaresta obscuriventris
(Loew, 1873) (Fig. 1B)

MATERIAL. NEW CALEDONIA: 1♂, Mandjelia, lower creek, 600m, 20°24'S, 164°31'E, 12.xii.2004, G. Monteith, MV light, rainforest; 4♂♂, 8♀♀, Fausse Yate bridge, 5m, 22°10'S, 166°56'E, 22.iv.2005, G.B. Monteith, beating (all QM).

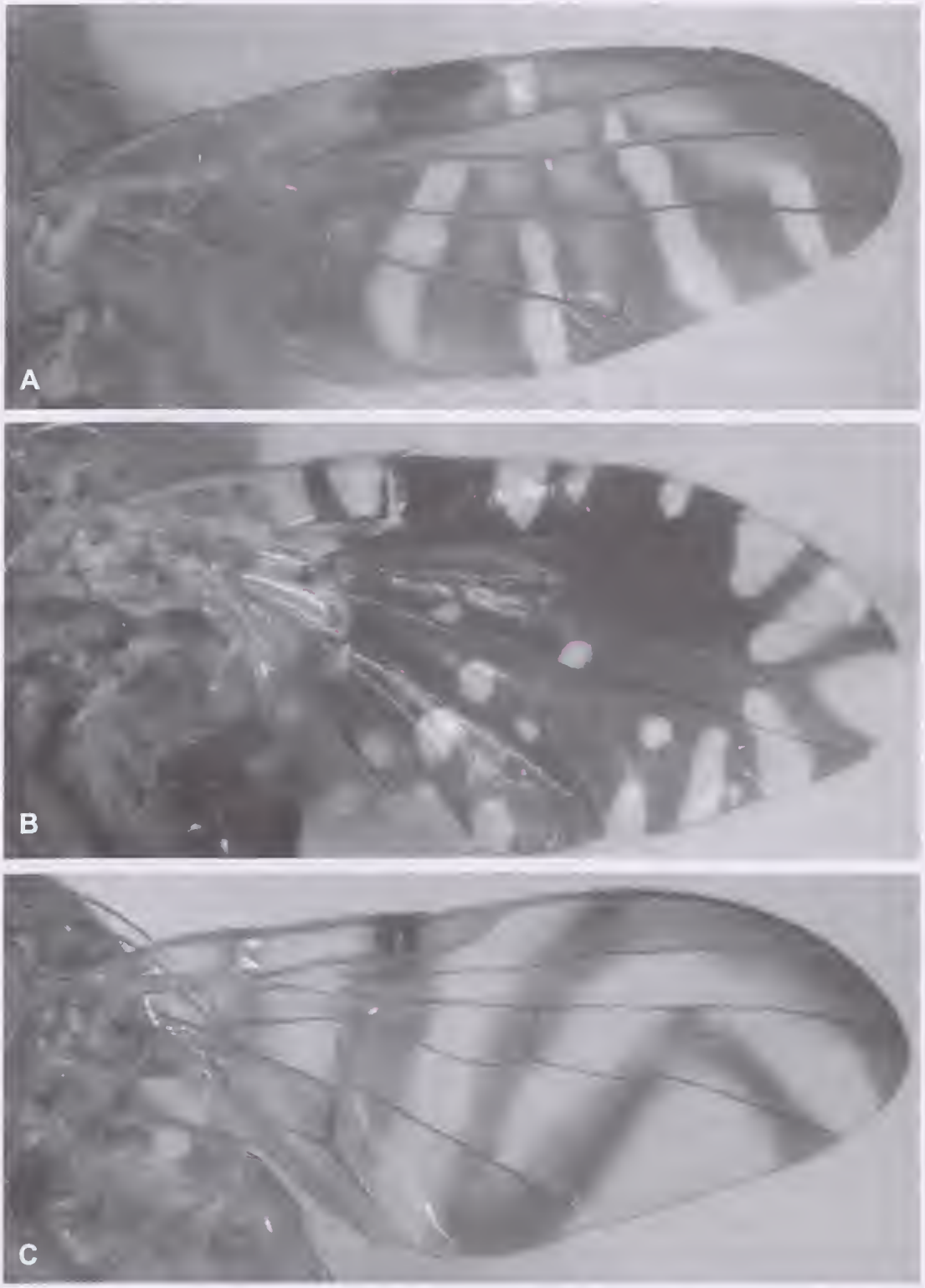

FIG. 1. Wings. (A) *Oedaspis ouinensis* sp. nov.; (B) *Tetreuaresta obscuriventris*; (C) *Ornithoschema mallochi*.

COMMENTS. This Neotropical species has a distinctive wing pattern (Fig. 1B) and appears to be widespread in New Caledonia. Originally introduced to Hawaii and Fiji for the biological control of *Elephantopus mollis* (Asteraceae), it also occurs in Tonga (Hancock & Drew, 1994; Norrbom & Hancock, 2004).

Subfamily TRYPETINAE
Tribe Adramini
Euphranta hardyi
Norrbom & Hancock, 2004

MATERIAL. NEW CALEDONIA: 2♂♂, 4♀♀, Mandjelia summit, 20°24'S, 164°32'E, 780m, 11-12.xii.2004, G. Monteith, rainforest, yellow pans (QM).

COMMENTS. This species is known only from New Caledonia.

Euphranta leichhardtiae
Permkam & Hancock, 1995

MATERIAL. NEW CALEDONIA: 1♂, Nehoue campground, 10m, 20°25'S, 164°13'E, 29.iv.2005, G.B. Monteith, MV light (QM).

COMMENTS. This species was described from eastern Australia (Permkam & Hancock, 1995) and first recorded from New Caledonia by Norrbom & Hancock (2004).

Piestometopon distinctum
(Permkam & Hancock, 1995)

MATERIAL. NEW CALEDONIA: 1♀, Nehoue campground, 20°25'S, 164°13'E, 29.iv.2005, G.B. Monteith, MV light, 10m (QM).

COMMENTS. This species was described from southeastern Queensland (Permkam & Hancock, 1995, as *Elleipsa distincta*) and is newly recorded from New Caledonia.

Tribe Rivelliomimini
Ornithoschema mallochi Hardy, 1992
(Fig. 1C)

MATERIAL. NEW CALEDONIA: 1♂, Nehoue campground, 20°25'S, 164°13'E, 29.iv.2005, G.B. Monteith, MV light, 10m (QM).

COMMENTS. This little-known species was described from Guam, Micronesia (Malloch, 1942; Hardy & Adachi, 1956, as *Cycasia oculata* Malloch) and is newly recorded from New Caledonia. The above specimen differs from the type series in details of the wing pattern (Fig. 1C): the transverse yellow-brown band across the R-M crossvein is connected to the costal band by a yellow area in cell r_1 and to the band across the DM-Cu crossvein along the wing margin in cell cu_1. All other characters appear identical, including the pair of distinct, shiny black bullae on abdominal tergite V and it is possible that the Guam series is teneral or faded. Pending the availability of further material, the New Caledonia specimen is regarded as conspecific. The name *O. mallochi* Hardy was proposed as a replacement name for the preoccupied *O. oculatum* (Malloch) (Hardy, 1992) and *O. pacifica* Hancock & Drew, proposed for the same reason (Hancock & Drew, 1994), is a synonym (Permkam & Hancock, 1995).

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CLIMBING PERCH (*ANABAS TESTUDINEUS*) (PERCIFORMES: ANABANTIDAE) ON SAIBAI ISLAND, NORTHWEST TORRES STRAIT: FIRST AUSTRALIAN RECORD OF THIS EXOTIC PEST FISH

GARRICK HITCHCOCK

Hitchcock, G. 2008 04 30. Climbing Perch (*Anabas testudineus*) (Perciformes: Anabantidae) on Saibai Island, northwest Torres Strait: first Australian record of this exotic pest fish. *Memoirs of the Queensland Museum* **52**(2): 207–211. Brisbane. ISSN 0079-8835.

The Climbing Perch (*Anabas testudineus*) has been recorded from Sabai Island in the Torres Strait, marking the first Australian record for this potentially invasive noxious fish species. Its biology and ecology and invasive history are reviewed. Measures to prevent the spread of this fish by human vectors to the Australian mainland are discussed. ❐ *Anabas testudineus, Climbing Perch, invasive fish, island colonisation, pest management, Saibai Island, Torres Strait.*

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Climbing Perch, *Anabas testudineus* (Bloch, 1792), has been declared a noxious fish in Queensland under the *Fisheries Act 1994* (Qld). It is listed under Section 74 of the *Fisheries (Freshwater) Management Plan 1999*, as it 'is found in the waters of southern Papua New Guinea and could be considered a threat to Australian waters' (State of Queensland, 1999: 7). Until recently, no wild populations of the fish were known in Australia (Department of Primary Industries & Fisheries, 2005). Its presence has now been confirmed on Saibai Island (9°24'S, 142°41'E) in Torres Strait, far north Queensland.

On 25 November 2005 Mr Dugan Crothers, a water system engineer who regularly visits Saibai Island, observed several live Climbing Perch in a catchment pump near the island's dam. On 13 January 2006, he and a colleague, Mr Harry Yamashita, saw an individual fish 'walking' on the ground near the southwest end of the island's airstrip (Crothers, pers. comm., January 2006). Mr Yamashita photographed the fish (Fig. 1), and they passed the digital images to the Australian Fisheries Management Authority (AFMA) on Thursday Island. They in turn alerted the Queensland Department of Primary Industries and Fisheries (QDPI&F), the agency with responsibility for exotic pest fish. QDPI&F and the Queensland Museum subsequently confirmed the identification of the fish as Climbing Perch.

Following these reports, I travelled to Saibai Island in January 2006 in an unsuccessful attempt to secure a specimen, and to discuss aspects of its introduction and ecology with local people. Several Islanders quickly identified the fish from photographs and drawings, stating that during the current wet season, numbers of Climbing Perch were seen moving overland within the village, especially during or immediately after heavy rain. One man said that he had first seen the fish on Saibai Island some three or four years ago, suggesting that a wild population of the fish has been established on the island for some time.

BIOLOGY AND PHYSIOLOGY

The Climbing Perch is an extremely hardy, small, brown or dark greenish-brown fish, native to southeast Asia. It is highly adapted to life in a seasonal tropical environment. It can tolerate very turbid and brackish water conditions; possesses an accessory air-breathing organ that enables it to survive out of water for several days; and uses its highly mobile suboperculum and strong fin spines to pull itself over land to move between bodies of water. The fish has the ability to aestivate during the dry season. If unable to access permanent sources of water at the end of the wet, it will bury itself into the mud of drying water bodies, to emerge with the onset of the next rains (Allen, 1991; Davenport & Abdul Matin, 1990; Department of Primary Industries & Fisheries, 2005; Forselius, 1957; Rahman, 1989; see also Froese & Pauly, 2007 for more information and references).

The species was introduced to Indonesia's Papua Province, in New Guinea, from elsewhere in the Indonesian archipelago, probably by transmigrants, who have brought this and other food fishes with them when settling the Province.

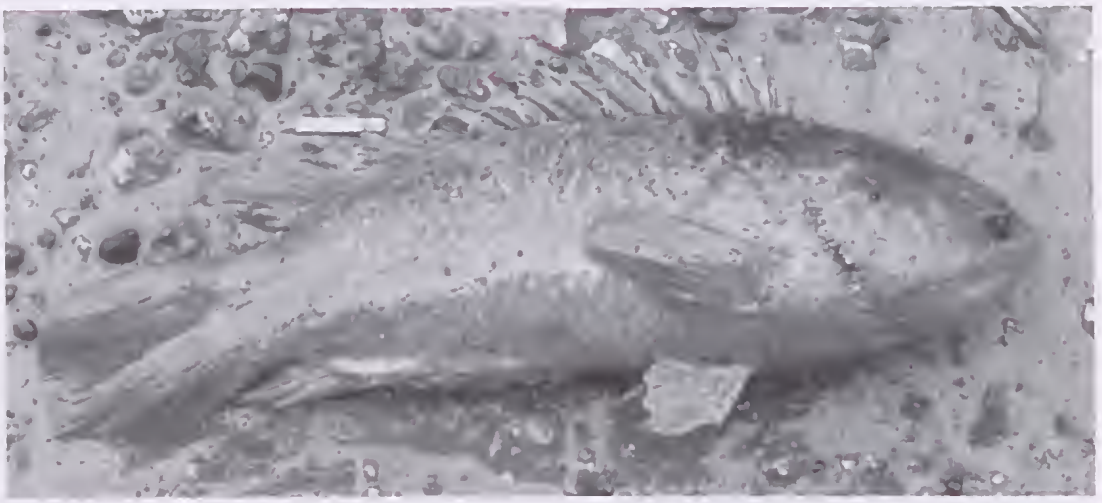

FIG. 1. *Anabas testudineus* on Saibai Island, 13 January 2006. Approx. total length 200mm. (Photo by Harry Yamashita).

It subsequently moved aeross the international border into Papua New Guinea (PNG), some time between the mid-1970s and mid-1980s, and has since spread rapidly eastward throughout coastal and riverine areas of southwest PNG (Allen, 1991: 215; Coates, 1989; Hitchcock, 2002; Storey et al., 2002; Miller et al., 1995; Swales et al., 1999).

Storey et al. (2002: 113) has highlighted how Climbing Perch's physiology, and local circumstances in Torres Strait, greatly increases the possibility of a successful deliberate or unintentional translocation of the fish into northern Australia:

> "The ability of *A. testudineus* to stay alive out of water poses a possible threat to the north of Australia. It is feasible that *A. testudineus* could unintentionally be introduced to Cape York, the north-east point of Australia, through the frequent movement of small craft across the Torres Strait from PNG to Australia; *A. testudineus* may survive in the moist conditions in the bottom of a boat for several days and the distance across the Torres Strait may be covered in a few hours. Once present, *A. testudineus* would quickly become established in the abundant suitable habitat found in the wet tropics of northern and north-eastern Australia."

The establishment of this fish on Saibai Island is not surprising, as it is located only 4 km from the PNG coast. Introduction by visiting Papuans cannot be ruled out, and it is possible that it could have been translocated live from the PNG mainland by waterbirds or birds of prey; specimens of dead *A. testudineus* have been identified among fish regurgitated by Australian Pelicans, *Pelecanus conspicillatus*, on Kerr Islet (9°37'S, 141°34'E) in Torres Strait, located 115 km westsouthwest of Saibai Island (Hitchcock, in press). However, a more parsimonious explanation is that the fish have been able to colonise the island as a result of a combination of environmental conditions. During the wet season, lower salinity levels prevail in northern Torres Strait, and a freshwater feature occurs along the PNG coast, due to outputs from PNG rivers, including the Fly (Ayukai & Wolanski, 1997; Pitcher et al., 2004). There are reports of heavy rainfall flushing Climbing Perch out of coastal rivers and creeks into Torres Strait. Lawrence (1995: 19) reports that an ebb tide at the PNG coastal village of Kadawa, situated northeast of Saibai Island, has left large numbers of *A. testudineus* flapping on the sand in front of this settlement.

Saibai Island is a low, muddy island, fringed by tidally inundated mangroves. The interior consists of seasonally inundated, fresh- and brackish-water sedge swamps, saltpans, and non-inundated claylands covered by grasslands and open woodland (see Barham, 1999; Barham & Harris, 1985; Environmental Science & Services, 1994). Climbing Perch have probably colonised Saibai Island via the system of mangrove creeks that connect the swamps to the sea, or king tides associated with the northwest monsoon, which flood low-lying areas. While most swamps are semi-permanent, several indigenous wells, and more recent water supply ponds and dams, retain fresh water throughout the dry season. Coupled

with the fish's ability to bury itself into mud, it seems likely that the Climbing Perch seen on Saibai Island are part of a viable, self-sustaining population.

IMPACTS AND CONTROL

Climbing Perch is known to kill some fish, waterfowl and reptile species that predate on it – its sharp spines becoming locked in the predator's throat or stomach (Lawrence, 1995; Miller et al., 1995; Storey et al., 2002). Like many other exotic introductions in Australia and New Guinea, it probably also competes with native fishes for space and food (Allen, 1991; Department of Primary Industries, 2001; Storey et al., 2002). Its potential impacts on the Saibai Island environment are unclear, as little is known about the island's fauna, however, the following native fish were collected from two freshwater locations close to where Climbing Perch were reported on the island (Queensland Museum catalogue numbers provided): *Megalops cyprinoides* QM I.38040, *Melanotaenia splendida rubrostriata* QM I.38037, *Ambassis agrammus* QM I.38038, *Ammiataba candavittata* QM I.38039, QM I.38043, *Selenotoca multifasciata* QM I.38042 and *Bostrychus zonatus* QM I.38041. Fortunately, Torres Strait effectively serves as a natural barrier to the spread of Climbing Perch to islands to the south of Saibai Island, and to the Australian mainland.

QDPI&F has in place a strategy for the control of exotic pest fishes (Department of Primary Industries, 2001). A key goal of the strategy is preventing the establishment of additional noxious species in Queensland. The Department has alerted local authorities in Torres Strait (including AQIS staff) about Climbing Perch on Saibai Island, and is developing a plan to monitor and manage this latest alien incursion. While it may not be possible to eradicate the fish from Saibai Island itself, the potential for transmission by human vectors to the Australian mainland will require ongoing vigilance. Considerable movement of people occurs throughout Torres Strait. This includes cross-border visits by Papuans and Torres Strait Islanders under the terms of the Torres Strait Treaty between Australia and PNG (Department of Foreign Affairs & Trade, 1985), mostly by PNG nationals, from villages on the Western Province coast to Torres Strait Island communities, but also movement by Torres Strait Islanders to the Australian mainland, and temporary visits to outer islands by non-Indigenous workers. The undetected arrival of a boat on western Cape York in January 2006, carrying asylum seekers from Indonesia's Papua Province, also highlights the potential, however low, for this species to be introduced directly to northern Australia by vessels originating from New Guinea.

The Australian Quarantine and Inspection Service (AQIS), through its Northern Australia Quarantine Strategy (NAQS), is charged with protecting northern Australia from animal and plant pests, and has a high profile in Torres Strait. On each Torres Strait community island, local AQIS officers ensure that people do not import or export prohibited items. Further, members of NAQS make regular patrols with their PNG counterparts along the PNG–Indonesian border. However, the focus of AQIS to date has been on exotic animals, insects, plants and diseases (see Thompson et al., 2003). While AQIS officers would seize and destroy this and other alien fish if they were detected being imported into Australia from PNG, responsibility for the natural dispersal and control/eradication of pest fish rests with QDPI&F (Shayne Ahboo, Manager Torres Strait and Northern Peninsula Area, NAQS, AQIS, pers. comm., May 2007).

Until recently, there was no national strategy to deal with exotic freshwater pest fish. However, the Vertebrate Pests Committee, an Australian/New Zealand government advisory group on pest animal management, has now expanded to include freshwater fish species, and in 2006 released a draft 'Australian Pest Animal Strategy' that includes fish (Agtrans Research & Dawson, 2005; Vertebrate Pests Committee, 2006). Furthermore, a draft national strategy for ornamental fish released in 2005 (Marine & Coastal Committee, 2005) proposed listing *A. testudineus* as a noxious fish in all Australian jurisdictions. In November 2006 the Natural Resource Management Ministerial Council endorsed the final version of the strategy (National Resource Management Ministerial Council, in press), with Climbing Perch on the list of nationally agreed noxious species. It also outlines a national approach to managing the aquarium fish trade and dealing with associated pests and diseases (Bureau of Rural Sciences, 2007a). An Ornamental Fish Management Implementation Committee has recently been created to progress the strategy (Bureau of Rural Sciences, 2007b). It is to be hoped that these national, cross-jurisdictional policy and statutory initiatives will result in effective management outcomes,

including enhanced surveillance, detection and response.

Cooperation, liaison and planning at all levels (local, regional, state and Commonwealth), ongoing awareness training by QDPI&F for local AQIS officers and staff of Island Councils, and an educational campaign in Torres Strait and adjacent areas of Cape York, will be crucial to preventing the spread of this fish by human vectors to the Australian mainland.

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HYPSILOPHODONTID (DINOSAURIA: ORNITHISCHIA) FROM LATEST ALBIAN, WINTON FORMATION, CENTRAL QUEENSLAND. *Memoirs of the Queensland Museum 52(2): 212.* The first and youngest recorded occurrence of fossilised remains of hypsilophodontids are in Queensland. Evidence of abundant small ornithopod dinosaurs were indicated by trackways in the Winton Formation (Thulborn & Wade, 1984), however, this is the first skeletal evidence. Numerous hypsilophodontid dinosaur remains, including cranial and postcranial specimens have been described from the Aptian and Albian of Victoria (Rich, 1996) (Fig 1a-b). Hypsilophodontids have also been described from Albian deposits of northern New South Wales Griman Creek Formation (Fig 1c), including *Fulgurotherium australe* Huene 1932 and an undescribed taxon (Molnar & Galton, 1986); so it is noteworthy, but not surprising that hypsilophodontid remains are present in younger sequences within the Great Artesian Basin.

The single specimen described here was recovered from sievings derived from excavations within 40m of the stratigraphic base of the Winton Formation. Designated by Burger (1986) within the upper *Phimopollenites pannosus* palynomorph Zone, Dettman & Clifford (2000), and others (e.g. Pole, 2000) have designated a latest Albian age for the lower Winton Formation. Clifford & Dettmann (2005) assign a latest Albian age to their type locality of *Tempskya judithae*, the same locality from which the present remains are described; Belmont Station, northeast of Winton, central Queensland (Fig 1d).

Description. QMF52774 (Fig 2) is an isolated right maxillary tooth bearing a well formed crown and a single root. Tooth crown split, labial crown face preserved, lingual crown face missing. Crown length: 3.96mm; crown height: 2.68mm. Single prominent primary ridge divides labial tooth crown in two, running to the base of the crown. Secondary ridge extends anteriorly at approximately 1/3 of length from primary ridge tip, does not fully divide from the primary ridge. Three distinctive secondary ridges extend from anterior crown base, forming cuspules, reduced in size anteriorly. Fourth, tiny cuspule emergent on anterior margin. Anterior margin of tooth crown curved, terminates at root, forming a distinctive neck. Posterior tip of primary ridge broken and worn. Posterior to primary ridge, four heavily faceted secondary ridges, extending from crown base to form distinct cuspules. First cuspule posterior of primary ridge largest and heavily worn below tip. Remaining posterior cuspules smaller posteriorly, all heavily worn. Posterior margin of tooth crown angulate and terminates above the line of the anterior margin.

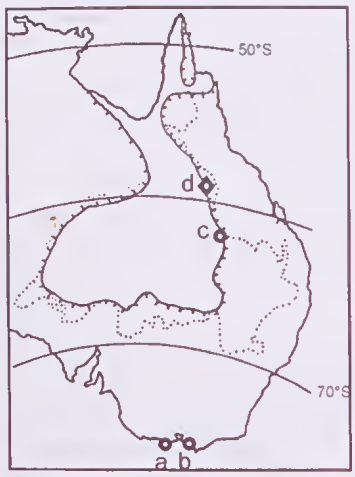

FIG 1. The Late Albian of eastern Australia showing the extent of the inland sea and localities. a. Otway Ranges (Albian), Victoria, b. Strzelecki Ranges (Aptian), Victoria, c. Lightning Ridge, Griman Creek Formation (Albian), New South Wales d. Belmont Station, Winton Formation (late Albian – Cenomanian), Queensland.

FIG 2. A. QMF52774, hypsilophodontid tooth in labial profile (scale bar = 2mm). B. Close up of tooth crown showing posterior ware facet (scale bar = 1mm).

Remarks. QMF52774 is similar to maxillary teeth of the hypsilophodontids, *Atlascopcosaurus loadsi* Rich & Rich (1989) and *Qantassaurus intrepidus* Rich & Vickers-Rich (1999) described from the Aptian-Albian deposits of southern Australia. These taxa share with QMF52774 the prominent primary ridge, 7-8 similarly strong secondary ridges and the curved anterior margin. Although QMF52774 is very small, it is not outside the size range of *Atlascopcosaurus loadsi*.

Acknowledgements. We thank David and Judy Elliott and the Australian Age of Dinosaurs Museum.

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8 June 2007.

A NEW SPECIES OF FRESHWATER CRAYFISH (CRUSTACEA: DECAPODA: PARASTACIDAE) FROM THE FLY RIVER DRAINAGE, WESTERN PROVINCE, PAPUA NEW GUINEA

CHRISTIAN LUKHAUP AND BRETT HERBERT

Lukhaup, C. & Herbert, B. 2008 04 30. A new species of crayfish (Crustacea: Decapoda: Parastacidae) from the Fly River Drainage, Western Province, Papua New Guinea. *Memoirs of the Queensland Museum* **52**(2): 213–219. Brisbane. ISSN 0079-8835.

A new species of crayfish *Cherax* (*Cherax*) *peknyi* is described from the Fly River drainage, in the western province region of Papua New Guinea. This species differs from all others in its subgenus by the shape of the rostrum, and chelae, and in colouration.
❐ *Cherax, new species, freshwater, crayfish, Fly River, Papua New Guinea, Indonesia.*

Christian Lukhaup, Gotenstrasse 16, 71336 Bittenfeld, Germany (email: Chris@crusta10.de). Brett Herbert, Animal Biosecurity (Aquatics); Biosecurity Australia, GPO Box 858, ACT 2601, Australia (email: Brett.Herbert@biosecurity.gov.au); 19 December 2007.

Crayfish were collected at various locations in the Fly River catchment in 2005–2006, as part of a project aimed at developing techniques for aquaculture of indigenous species of *Cherax*. Techniques for sustainable aquaculture of Red-claw crayfish (*Cherax quadricarinatus*) were developed in Queensland in the 1990s, and it was hoped to adapt such techniques for similar species in Papua New Guinea. Crayfish are known to be present in the Fly River floodplain, and in the foothills of the mountains near the provincial capital of Kiunga. They are collected and eaten in all regions, particularly when the water level has receded during the dry season. The people knew of a crayfish with a soft red patch on the claws of the males (as has *Cherax quadricarinatus*), but when we went collecting with them, they caught several species including the undescribed *Cherax peknyi*. Specimens were forwarded to Queensland Museum to ensure their presence was documented — particularly important as some species are disappearing from the Fly River floodplain following the introduction of exotic predators such as the fish *Anabas testudineus* and *Channa* sp.

Specimens collected in Tamu Creek (a tributary of the Fly River in the Western Province of PNG) in 2006, were tentatively assigned as *Cherax* sp. "*papuana*" by BH. We realised that these specimens perfectly matched the species from the Merauke region introduced onto the German pet market as *Cherax* sp. "tiger" and *Cherax* sp."zebra" in the year 2000, and which the senior author believed to be a new species. New Guinea has been the source for a highly lucrative trade in native fish from West Papua to Europe, in particular a number of rainbowfish species. The pretty colour patterns of this crayfish, and the ease with which it can be transported, makes it of particular interest to the aquarium trade. Crayfish collected from wild populations are supplied by wholesalers to the European, Japanese and USA pet markets. We here describe this distinctive crayfish as a new species, *Cherax peknyi*.

The project is an ACIAR and Ok Tedi Mining Limited funded QDPI&F, Ok Tedi Mining Limited, Western Province Government and National Fisheries Authority project.

Abbreviations. cl. = carapace length; OCL = orbital carapace length. QM = Queensland Museum, Brisbane; RMNH = Rijksmuseum van Natuurlijke Historie, Leiden, Netherlands; tot. l. = total length of carapace and abdomen.

TAXONOMY

PARASTACIDAE Huxley, 1879

Cherax (Cherax) peknyi sp. nov.
(Figs 1–3, Table 1)

MATERIAL EXAMINED. HOLOTYPE, QMW28267, ♂ (cl. 44mm), Tamu Creek, Fly River Drainage, Western Province, PNG, 7°34' S, 141°03' E, altitude 200m, 12.10.2006, Brett Herbert.

PARATYPES: RMNH-D51760, 1♂ (CL. 42mm) same data as holotype. QMW28384, allotype ♀ (cl. 35mm), High School Creek, Fly River Drainage, Western Province, PNG, Oct. 2006, Brett Herbert. QMW28385, 4 ♂♂ (tot. l 48–87mm), 6 ♀♀ (tot. l. 56–79mm), same data as holotype.

DESCRIPTION. (Based on holotype.) Body subovate, slightly compressed laterally. Pleon narrower than cephalothorax (c. 0.9) . Cervical

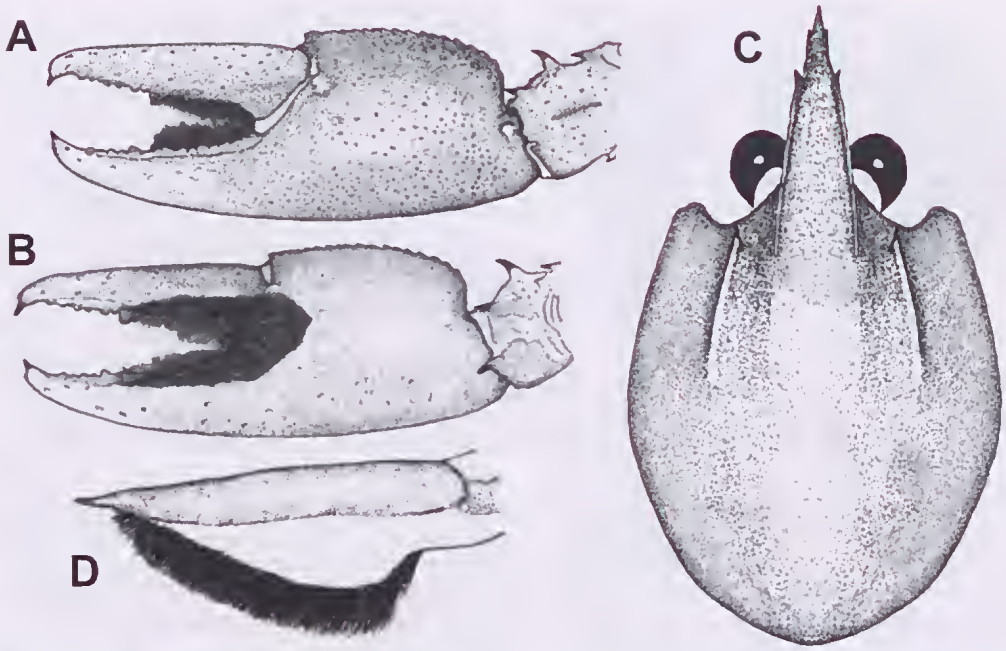

FIG.2. *Cherax* (*Cherax*) *peknyi* sp. nov. male holotype. A, dorsal view left chela; B,ventral view left chela; C, dorsal view of carapace; D, scaphocerite.

TABLE 1. Measurements (mm) of holotype and paratype speeimens of *Cherax* (*C.*) *peknyi* sp. nov.

	Carapace	Pleon	Total length	Chela height	Chela length	Chela width
Holotype male	44	48	92	9	41	16
Male 2	42	45	87	8	38	14
Male 3	—	—	55	—	—	—
Male 4	—	—	48	—	—	—
Male 5	—	—	48	—	—	—
Allotype Female	35	39	74	6	28	11
Female 2	34	38	72	6	27	11
Female 3	32	36	67	6	23	10
Female 4	—	—	79	—	—	—
Female 5	—	—	72	—	—	—
Female 6	—	—	61	—	—	—
Female 7	—	—	56	—	—	—

groove distinct. Carapace smooth anterior to eervical groove; 3–4 anteriorly directed spines placed together just behind cervical groove laterally at about level of antenna; some short scattered setae present in cervical groove adjacent to lateral spines. Areola c. 2.4 times longer than breadth at narrowest point; and occupying about one-third of total carapace length. Rostrum slender, reaching to about end of ultimate antennular peduncle, and about twice as long as wide at base; upper surfaee smooth; lateral margins almost straight basally, distally tapering quickly near apex; margins elevated, ending in carapace rostral carinae; lateral margins bearing 2 prominent teeth; distal half of outer margins bearing a few short setae. Rostral teeth point dorsally at about 45° angle. Rostral carinae extending as slight elevation over anterior half of carapace, then fading posteriorly. Postorbital ridges well developed, terminating in slightly upturned corneous spines anteriorly; fading after 2/3 of OCL posteriorly. Seaphocerite broadest medially, convex over distal part, becoming narrower basally; thickened lateral margin terminating in large corneous spine; c. 3.7 times longer than broad. Antennules and antennae of typical shape. Eyes relatively large; cornea globular, darkly pigmented, about as long as eyestalk; eyestalk slightly narrower than cornea. Epistome broadly triangular, becoming lanee-

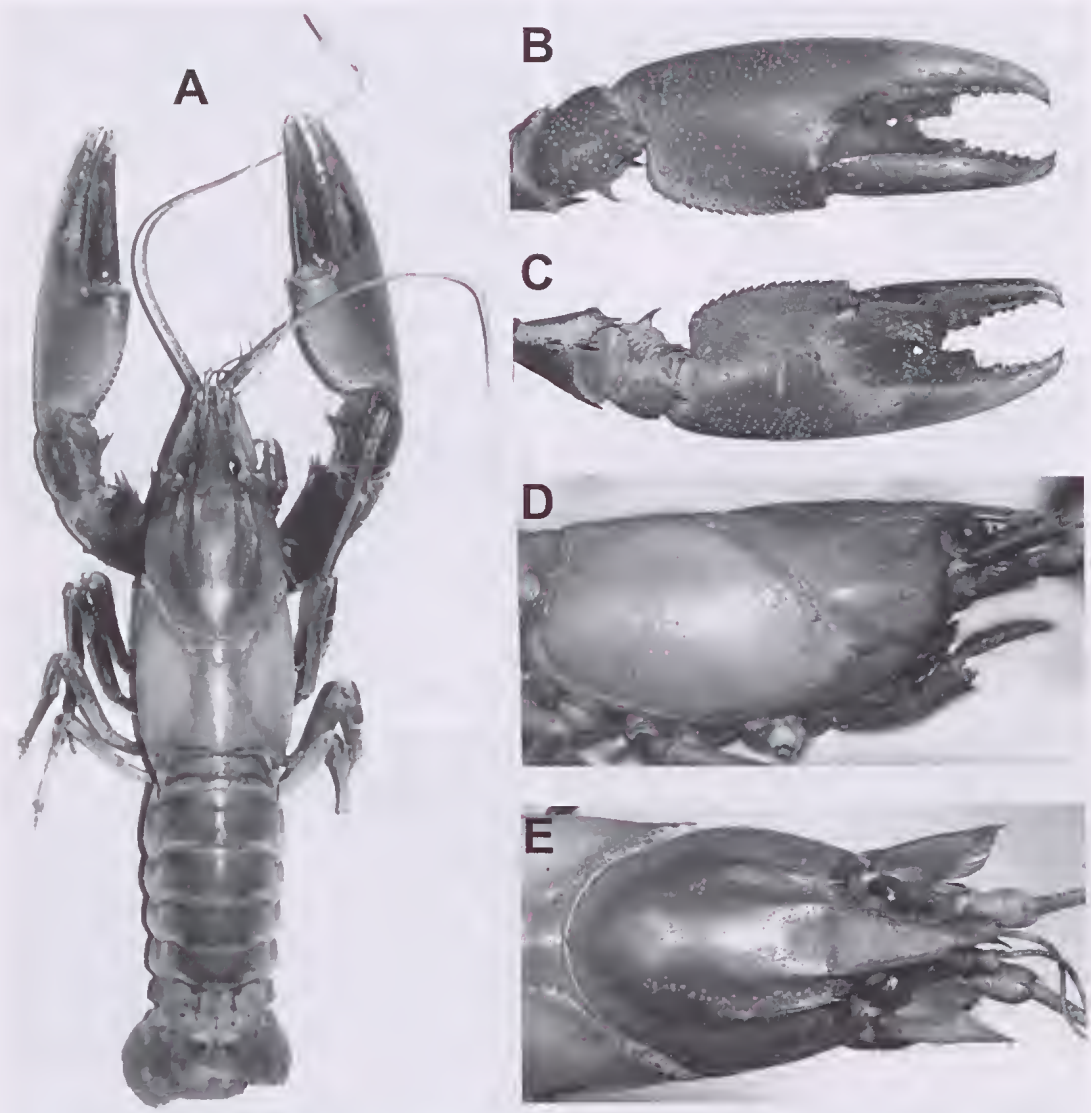

FIG. 2. *Cherax* (*Cherax*) *peknyi* sp. nov. male holotype. A, dorsal view; B, right first chela, dorsal view; C, ventral view; D, lateral view of the carapace; E, dorsal view of cephalon and rostrum.

shaped anteriorly; lateral surface with many small tubercles; central part smooth, excavate.

Holotype male with chelipeds equal in form and size. Chela c. 4.5 times longer than high; c. 2.6 times longer than deep, strongly compressed. Fingers longer than palm, slightly gaping. Dactylus broad at the base, tapering slightly towards tip; tip with sharp, hooked tooth pointing outwards at 45° angle; cutting edge with 11 relatively small granular teeth, and one slightly bigger tooth medially; ventral and dorsal surface with scattered pits. Propodus triangular; fixed finger terminating in sharp, corneous, hooked tooth, standing almost perpendicular to axis. Upper surface of palm smooth, slightly pitted, more densely pitted at margins. Ventrally with dense setae present at base of moveable finger, covering anterior third of propodus and extending about half way along the gape becoming increasingly scattered and shorter anteriorly. Carpus with mesiolateral part slightly elevated to form slender serrated ridge with row of 16 small blunt spines; some small tubercles present along this ridge becoming increasingly scattered anteriorly; ventral surface

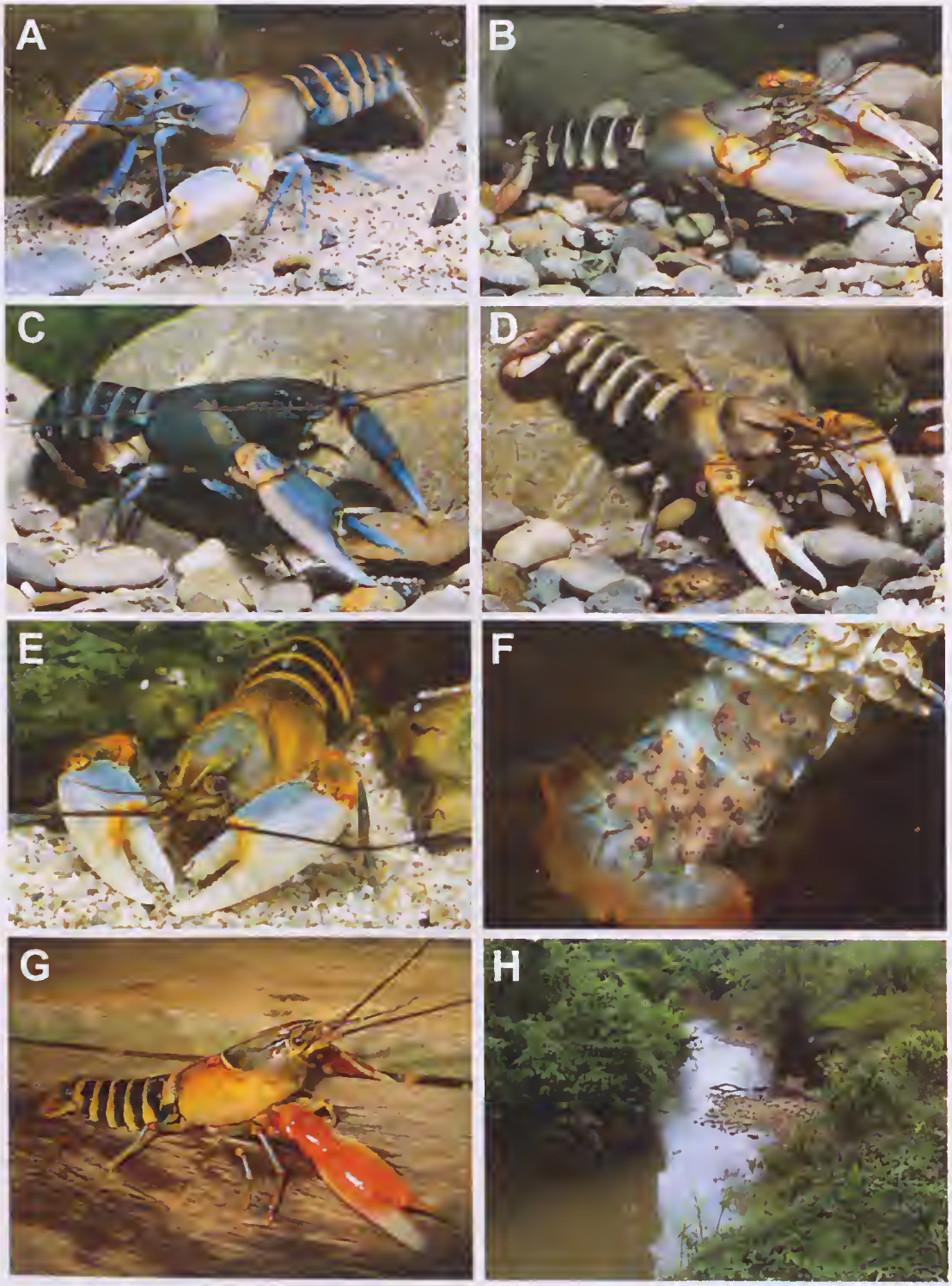

FIG. 3. *Cherax peknyi* sp. nov. A–E, specimens from aquarium shops; F, female with larvae; G, wild-caught specimen from Fly River catchment; H, creek close to Kiunga showing typical habitat.

smooth, pitted, with median portion elevated to form low, broad ridge. Merus with dorsal surface smooth, densly pitted, with a slight excavation medially; 1 small spine present mesiolaterally; 1 acute corneous spine also present dorsolaterally; ventral surface with two large corneous spines; some small granules at ventrolateral margin. Ischium smooth with single spine on dorsal surface; row of three spines on ventral surface and row of 10–12 small granules on ventrolateral margin; base with single spine on ventrolateral margin.

Second leg reaching to about end of scaphocerite; fingers slightly longer than palm; carpus c. twice length of palm; merus c. 1.4 times longer than carpus; ischium about half as long as merus. Third legs reaching farther than second; fingers shorter than palm. Fourth legs slightly shorter than second; dactylus ending in corneous tip; short setae on ventral side of propodus; propodus about twice length of dactylus and slightly longer than carpus, somewhat flattened, and carrying many bristles on lower margin; merus longer then propodus. Fifth legs similar to fourth; shorter and more slender.

Dorsal surface of abdomen smooth medially; pleura smooth, pitted. Telson with two spines at caudolateral corners. First uropod with two well defined spines; distal spine on mesial lobe; with prominent median rib ending in spine; exopod divided horizontally by row of small spines ending in distal spine on mesial lobe.

Allotypic female with chelipeds equal (right cheliped damaged), more than 2.5 times as long as broad; mesiolateral part of carpus slightly elevated to form slender serrated ridge with row of 17 small spines; cutting edge of dactylus with relatively small granular teeth in posterior part, and one slightly larger tooth at about middle of cutting edge; cutting edge of fixed finger bearing small granules, two being slightly larger; low short setae visible along ventral cutting edge of fixed and moveable fingers, thicker posteriorly. Cervical groove distinct, non setose; carapace smooth anterior to groove; 1 weakly developed, anteriorly directed spine present closely behind groove laterally at level of antenna . Abdomen slightly narrower than cephalothorax. Chelipeds of young males resemble those of females, or slightly broader.

Colouration. Body colour variable (Fig. 3). The crayfish of the type series collected in Tamu creek (Fig. 3G) and High School creek are coloured (in life) as follows: chelae red to orange fading to pinkish white anteriorly; distal tip bluish grey. Legs (except for first pair) greenish grey with orange joints. Cephalic region greenish gray fading to a yellowish green laterally; dorsal thoracic region brown-orange fading to yellow laterally and becoming cream ventrolaterally. Pleon green with broad yellow bands. Telson green, becoming yellow to orange mesolaterally. Distal margin of tail-fan pale orange.

Size. Largest males examined reached 92mm total length; largest female 79mm total length.

SYSTEMATIC POSITION

The modern use of subgenera within *Cherax*, seems to have started with Holthuis (1996) who used *Cherax* (*Astaconephrops*) for a new species from New Guinea. This *Astaconephrops* group is used for all *Cherax* species that have a soft decalcified section on the outer distal margin of male claws. This is a distinctive morphological apomorphy, and its usefulness as a character to split the genus has been supported by a recent molecular study by Munasinghe et al. (2004), who found a very well supported monophletic lineage for this group, that is sister to all other species of *Cherax* sensu stricto. We therefore support the concept of two subgenera within *Cherax* and use this here. The New Guinea species of *Cherax* (*Cherax*) so far number ten, viz: *Cherax boschmai* (Holthuis, 1949); *Cherax buitendijkae* (Holthuis, 1949) ; *Cherax communis* (Holthuis, 1949) ; *Cherax longipes* (Holthuis, 1949) ; *Cherax murido* (Holthuis, 1949) ; *Cherax pallidus* (Holthuis, 1949) ; *Cherax panaicus* (Holthuis, 1949) ; *Cherax papuanus* (Holthuis, 1949); *Cherax solus* (Holthuis, 1949) ; *Cherax holthuisi* (Lukhaup & Pekny, 2006). *Cherax peknyi* sp. nov. can be separated from all other Papua New Guinea species within the subgenus by the shape of the rostrum, and chelae, and in colouration (see Table 2). In particular, the patch of dense setae in the proximal half of the gape of the chela, and the presence of 3–4 cervical spines are diagnostic of this species. Also only two other species have only two lateral rostral teeth, *C. pallidus* and *C. papuanus*, and these are easily separated from *C. peknyi* sp. nov. using the aforementioned characters.

HABITAT AND LIFE HISTORY. The crayfish were usually found in slow flowing, still water, in parts of southern New Guinea with pronounced wet and dry seasonality. The villagers traditionally collect these animals when the water levels are low

TABLE 2. Comparison of characters useful for separating *Cherax (Cherax) peknyi* sp. nov. from other related species occurring in Papua New Guinea.

	Rostral teeth	Chelae	Carapace	Other
C. peknyi	2	dense setae on posterior part of cutting edges; fingers 3.3 x longer than broad	smooth, 3–4 cervical spines present	yellow or pale stripes on the pleon
C. boschmai	5–7	more slender; fingers c. 1.5 x longer than palm	covered with small tubercles	small eyes; scaphocerite broad
C. buitendijkae	4–6	more slender; fingers c. 1.4–1.5 x longer than palm	covered with tubercles	large eyes; scaphocerite broad
C. communis	5–7	broader, few setae on ventral cutting edge	covered with small tubercles	larger eyes; scaphocerite broad
C. longipes	3–5	4 x longer than broad	numerous tubercles	small eyes; legs extremely long and slender
C. murido	4–6	3 x longer than broad	covered in tubercles	large, globular eyes
C. pallidus	2–4 (mostly 2–3)	6.5–8 x longer than broad; fingers 1.7 x longer than palm, extremely slender, tips crossing	densely covered in tubercles	eyes extremely large and globular
C. panaicus	5–8	more slender (3.5–4 x longer than broad); fingers 1.5 x longer than palm	covered with small tubercles	known only from Panai Lake, West Papua
C. papuanus	2	2.5 x longer than broad; fingers 2.5 x longer than broad	smooth and pitted, no cervical spines	endemic in Lake Kutubu, at 800m elevation;
C. solus	3–4	slender	covered with tubercles	endemic in Tigi Lake, West Papua
C. holthuisi	2 indentations, no spines	few short setae on cutting edges of chelae	smooth	small eyes, described from Aitinjo Lake, West Papua

during the dry season, as in most places the water flow is too fast in the wet season. Clarity of the water depends on the level of flooding and time. The Tamu River (near the West Papua border) is muddy during the flood season, becoming clear after the initial floods, and then becoming stagnant, with dark (tannin stained) water full of rotting leaves, and almost anaerobic (DO<1mg/L) in the dry season. The crayfish live under logs and in crevices and holes in submerged timber. They also live in burrows in the clay in the banks of the river. Even when the water is very low in dissolved oxygen they live in all water depths and in their holes. No berried females were collected in the dry season suggesting that breeding is in the wet season.

Generally the habitat is in monsoon gallery forest, however they persist where habitat modification has been severe (clearing and siltation), and breed and maintain populations in small creeks around Kiunga (e.g. near the Kiunga school). These modified creeks have moderate flow throughout the year, and are highly turbid (secchi <50mm), and DO >4mg/L. Water temperature in small streams around Kiunga gets as low as 18°C, and up to 29°C. A few of the creeks in which they occur dry out completely, so they probably are able to survive in moist conditions for a couple of months, in burrows or moist logs.

We did not collect crayfish in the swamps, and the villagers only fish for crayfish in rivers in the forest behind the swamps. No crayfish have been collected in the main Fly River channel which is heavily populated by *Macrobrachium rosenbergii*. In the streams *Cherax peknyi* was sympatric with *C. albertisii* and *C. quadricarinatus*, which are also collected for food by the local people during the dry season.

ETYMOLOGY. Named after Mr Reinhard Pekny, for his untiring efforts in protecting freshwater crayfish, and his contribution to our knowledge of the breeding and behaviour of New Guinea crayfish.

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FRESHWATER TURTLE POPULATIONS IN THE BURNETT RIVER

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A study was conducted on freshwater turtle populations residing in a section of the Burnett River to be flooded by the Paradise Dam. Four species were found with *Emydura macquarii krefftii* being the most common. The population of this species was bias towards adult sized turtles, with poor recruitment or low survivorship of hatchlings. The size at which 50% of the population had reached adulthood was 18.2cm and 20.6cm for males and females respectively. *Elseya albagula* and *Wollumbinia latisternum* occurred at very low densities. Both these species also showed a population bias towards adult sized turtles, despite annual breeding by adults. *Chelodina expansa* was rare with only four individuals caught. Morphometric and reproductive characteristics for the three most common species will enable an assessment of the impact of the Paradise Dam on turtle populations. ❐ *Freshwater, riverine, turtles, impoundments, ecology, reproduction, growth.*

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Many species of riverine turtles are declining worldwide, and freshwater turtles are impacted by stream impoundments in a similar way to fishes and invertebrates (Bodie, 2001). The Burnett River in Queensland, Australia, is highly modified. The latest change has been the completion of the large Paradise Dam in 2005, however numerous other water infrastructures exist along the river's length. The potential threat from multiple impoundments to the system's five freshwater turtle species has four facets: habitat loss, habitat fragmentation, aquatic health and condition impacts, and barriers to dispersal and/or migration (Hamann et al., 2004).

In a study to investigate the impact of dams and weirs on freshwater turtle populations in Queensland's Fitzroy-Burnett-Mary Catchments, Tucker (1999) concluded that the loss of edible fruit from riparian vegetation, the loss of suitable nesting banks, and the loss of freely flowing sections of rivers, are likely to influence the diversity of species and population characteristics of freshwater turtle species in areas that become impounded. Studies within the Burnett River Catchment also show that impoundment structures not only frequently act as barriers to turtle movements, but can also cause high rates of injury and mortality to turtles washed over walls, or living in downstream water release areas (Hamann et al., 2004). Such impacts need to be monitored, and effectively managed, as they can affect population function and ultimately the survival of some species.

Effective management of natural turtle populations requires suitable baseline data for key population demographic parameters and morphological characteristics. These data can be used to identify populations currently under stress, those that have become stressed, and those that are recovering from stress (e.g. Gibbons et al., 2001, Romero & Wikelski, 2001, Fonnesbeck & Dodd, 2003). Limpus et al. (2002) conducted a 'pre-construction' baseline study of freshwater turtle populations in the area of the Burnett River to be flooded by the Walla (now known as Ned Churchward) Weir. Data from their study has been important in post construction monitoring at that weir. The present study provides such pre-construction baseline information on freshwater turtles at sites upstream and downstream of the Paradise Dam at AMTD 131.2 on the Burnett River, SE Queensland. Hopefully it will be

similarly useful for monitoring turtle abundance, diversity, health, and population demography, as the impacts of this new, and much larger, impoundment take effect.

MATERIALS AND METHODS

The undescribed *Elseya* species in Limpus et al. (2002) and Hamann et al. (2004) has been described as *Elseya albagula* Thomson, Georges and Limpus, 2006. Our study builds on the data for *E. albagula* presented by Hamann et al. (2004) using increased sample sizes, and information on an additional three turtle species.

STUDY SITE

Freshwater turtles were caught at six sites in the section of the Burnett River between AMTD 130 and AMTD 175. These sites included one site (Campbell's Property 25.3374°S, 151.9267°E) downstream of the Paradise Dam, the Paradise Dam site (25.3514°S, 151.9181°E), and four sites upstream of the Paradise Dam site but still within the area to be flooded by the impoundment (Paradise 25.3551°S, 151.8953°E, Goodnight Scrub 25.3582°S, 151.8785°E, Mingo Crossing 25.3984°S, 151.7773°E, and Gahans Road Crossing 25.4190°S, 151.6889°E). The number of days spent catching turtles at each site was not equal and ranged from two days at Mingo Crossing up to 28 days at Goodnight Scrub. While most turtles were sampled between 2002 and 2004, we have included 62 turtles (59 *Emydura macquarii krefftii* (Gray 1871) and 3 *Wollumbinia latisternum* (Gray 1867)) that were caught at Goodnight Scrub during 1997 or 1999 as part of a previous Queensland Parks and Wildlife (QPWS) study (Tucker, 1999). Most of the field work at all sites was conducted prior to the alteration of the river in June 2004, and the associated start of construction on the Paradise Dam. Eight days of field work occurred during the construction phase; two days at a 50m long shallow section of river (c.a. 0.5 to 1m deep) that was pumped dry during the construction process to allow the footings of the dam wall to be constructed; and six days catching turtles in the pools immediately up and downstream of the site of the dam wall.

The substrate within each section of the river was similar and comprised a mixture of sand and volcanic rocky substrate (Benjamin, 1995; Van Manen, 1999). At sampling locations water depths were generally less than three metres and the river consisted of pool-riffle-pool formations. *Callistemon* spp. grew along most banks and their branches often draped into the water providing in-stream structure. With the exception of the river bank associated with Goodnight Scrub National Park, riparian vegetation was limited in width (usually < 50m).

TURTLE CAPTURE AND DATA COLLECTION

Studies in other areas of the Burnett River Catchment have indicated that populations of freshwater turtles showed a low frequency of younger (immature) age classes. We therefore used a variety of capture methods over a range of microhabitats, and at different times of the year, in an effort to sample turtles of all age classes. Turtles were captured by snorkelling, trapping, dip-netting, seine netting or searching through the mud or shallow water (for method descriptions see Tucker, 1999; Limpus et al., 2002; and Hamann et al., 2004). Snorkel captures involved locating turtles visually while swimming underwater along the sides and bottom of the river and capturing them by hand. Three trap designs were used: submerged modified collapsible traps with wide funnel openings; floating modified collapsible traps with internal floats; and the cathedral trap version of the modified submerged collapsible traps (see Hamann et al., 2004 for description). Deployed cathedral style traps were positioned so that the top of the upper compartment was out of the water allowing turtles to surface and breathe. Traps were baited with a variety of fruit and/or meat products. Submerged traps were checked every 1–2 hours depending on water temperature. Cathedral style traps and floating traps were checked at least once every 24 hours. Dip-netting and hand captures were generally made while spotlighting at night on foot or from a boat. Use of seine nets was limited due to the rocky boulder substrate in this section of the river. Seine net mesh sizes ranged from 5.5cm to 15.2cm and nets were used singly or in combination. In the section of river that was pumped dry, once all the water was removed we were able to systematically work our way through the area searching by hand for any turtles that were under rocks or buried in the mud.

Turtles were tagged using the standard methods described by Limpus et al. (2002) and Hamann et al. (2004). Each turtle was tagged with a self-locking, self-piercing monel tag in the webbing of a hind foot and/or coded with one or more notches in the marginal scutes. In addition, during July

and August 2004 all turtles over 15cm straight carapace length (SCL) 39 *E. m. krefftii* and 3 *W. latisternum*) caught at the Paradise Dam site were tagged with passive integrated transponder tags (PIT) tags (23mm Eco-line RI-TRP-REHP) that were compliant with the anticipated inclusion of an automated tags PIT tag scanner in the fishway of the Paradise Dam. Morphological measurements were taken with vernier callipers as described in Limpus et al. (2002) and Hamann et al. (2004). Weight was measured either by electronic balance (± 0.05–1.0 g) or, for turtles over 3kg, a spring balance (± 50 g). Scute counts were conducted on most turtles when they were caught for the first time. Nomenclature of scutes follows Pritchard & Trebbau (1984) except that 'supracaudal' scutes are included in the marginal scute count. Plastron curvature was determined by placing a straight edge along the plastron and categorising plastron shape in relation to the midline axis of the turtle, as convex, concave, or flat. Gender of turtles was assessed by three ways: first, by laparoscope examination; second by using morphometric measurements (the relationship between tail size and carapace length); and lastly some females carrying oviducal eggs were identified as adults by palpation of eggs through the inguinal pocket (following methods of Limpus et al. (2002)). Laparoscopy allows the gonads of turtles to be examined visually to determine gender, sexual maturity, and breeding status (following the methods of Limpus et al. (2002) and Limpus & Limpus (2003)).

Growth layers on the carapace and/or plastron scutes were counted to record the minimum age of individual turtles where the entire growth sequence from the hatchling scute or the first-year growth layer remained visible (Hamann et al., 2004). For example, if a turtle had six growth layers separated by five rings, it was deemed to be in its sixth year. Only turtles for which the hatchling scute was visible have been included in this analysis. Each growth layer (annulus) on a scute is assumed to represent a year of growth.

The size at which 50% of the turtles are sexually mature (AS_{50}) was determined following the methods of Limpus et al. (2002). In short, the proportion of adult turtles in 1cm size classes was analysed using logistic functions. The goodness of fit was determined by the residual variance and log likelihood functions.

During the 2003 and 2004 breeding seasons for *E. albagula* (April to September, Hamann et al., 2004) the Gahan's Road, Goodnight Scrub, Paradise Dam and Campbell's property sites were searched to locate turtle nests. Determination of species was based on egg shell measurements and comparison with the key presented by Hamann et al. (2004). Nest searches were not conducted to identify nesting habitat of the spring–summer laying species *W. latisternum* and *E. m. krefftii*.

Unless otherwise stated, means are presented with standard deviations. Statistical significance was accepted at $p < 0.05$. Data that failed tests of normality were log transformed. Statistics

TABLE 1. Frequency of captures by method for freshwater turtles in the Paradise Dam area of the Burnett River.

Method	*Emydura m. krefftii*	*Elseya albagula*	*Wollumbinia latisternum*	*Chelodina expansa*
Snorkelling	131	16	2	2
Seine netting	2	0	0	0
Dip netting	14	0	0	0
Trapping	332	1	30	2
Night spotlighting	4	2	0	0
Drained pool search	4	0	1	0
Method not recorded	47	2	2	0
Killed by construction activities associated with the dam	0	0	1	0
Total	**534**	**21**	**36**	**4**

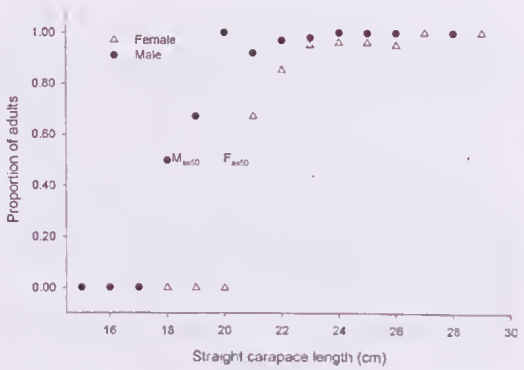

FIG. 1. Calculation of AS_{50} values for adult male and female *Emydura macquarii krefftii* from the Paradise Dam Area of the Burnett River (female logistic equation y = 0.9601/1+(SCL/20.81)^-90.50) and male logistic equation y = 0.987/1+(SCL/18.232)^-30.206). M and F correspond to the calculated AS_{50} for each sex.

were conducted using S Plus software (Krause & Olson 2002).

RESULTS

Four species of freshwater turtles were caught in this study. *Emydura macquarii krefftii* (Gray 1871) comprised 89.8% of captures; *Emydura albagula* Thomson, Georges and Limpus, 2006, 3.5%; *Wollumbinia latisternum* (Gray 1867), 6.0%; and *Chelodina expansa* (Gray 1857), 0.6%.

Emydura macquarii krefftii (Gray 1871)

POPULATION CHARACTERISTICS. *E .m. krefftii* was the most common turtle in the river. It was captured at all study sites, and by using each of the study methods. Most individuals were caught by either snorkelling or trapping (Table 1). Because the relationship between tail length and SCL is not a precise measure of sex or maturity, our analyses are based on animals for which sex and maturity were confirmed by laparoscopic examination or by the presence of oviducal eggs by palpation. Based on the data for which maturity was confirmed there is a wide range of sizes over which the transition from 100% immature to 100% mature occurred, and the range of sizes over which this transition occurred differed between sexes (Fig. 1). The relationship between size and maturity which provided the best estimate of the size at which 50% of the turtles were adult (± 95% confidence limits) was a logistic function that differed for each sex. For females: y = 0.9601/1+(SCL/20.81)^-90.50 and r^2 = 0.996; F = 1642.43; $P < 0.001$; F = 1670.36; $P < 0.001$. For males: y = 0.987/1+(SCL/18.232)^-30.206 and r^2 = 0.993; F = 1642.43; $P < 0.001$). In females the range of SCLs for 100% immature and 100% mature groups was 20–27cm, and the AS_{50} was 20.81 ± 0.04cm (Fig. 1). In male turtles the range of SCLs from 100% immature and 100% mature animals was 17–24cm, and the AS_{50} was 18.23 ± 0.04cm (Fig. 1).

The size class distribution by sex of captured *E. m. krefftii* shows a low frequency of individuals among the smaller age classes (Fig. 2). Of the 539 *E. m. krefftii* caught over the six sites within the study area there were: 191 confirmed as adults (74 males and 117 females); 222 that were either above the minimum breeding size but not assessed for maturity, and/or did not have their tail lengths recorded; 9 pubescent immature (6 females and 3 males); 21 sexed prepubescent immature (16 females and 5 males); and 96 that were not assessed for gender or maturity. The population sex ratio included the 191 individuals that had sex determined through laparoscopy and 79 females and 109 males for which sex, but not maturity, could be determined using tail length. Turtles with SCL < 27cm and tail lengths >5cm were classed as male and those with SCL> 21cm and tail lengths < 5cm were classed as female (Fig 3.). The resulting sex ratio (183 males and 196 females) is not significantly different to 1:1 F:M (X^2 = 0.90; P > 0.05).

Adult females were larger than adult males in all aspects except tail measurements (Table 2). A significant linear relationship occurred between log weight and log SCL for; all turtles (combined sexes and age classes) (r^2 = 0.96; df = 1,216; F = 2554.23; $P < 0.001$), females (combined age classes) (r^2 = 0.96; df = 1,135; F = 4194.91; $P < 0.001$) and male (combined age classes) (r^2 = 0.86; df = 1,80; F = 499.26; $P <$ 0.001). However, this log weight and log SCL relationship was significantly different between the sexes (ANCOVA; F = 59.32; df = 2, 216; $P < 0.01$). In addition, the log weight and log SCL relationships for turtles in our study were not significantly different to the relationship for turtles caught in the Burnett River prior to the construction of the Ned Churchward Weir (Limpus et al., 2002; ANCOVA F = 0.37; df = 1, 812; P = 0.54).

Adult female turtles caught in our study were similar with regard to both weight and length to those caught in the Burnett River prior to

the construction of the Ned Churchward Weir (Limpus et al., 2002; SCL = t test = 0.93; P > 0.05 and weight t test = 0.20; P > 0.05). However adult males from our study were both longer and heavier than those reported by Limpus et al. (2002) (SCL = t test = 4.30; P < 0.05 and weight = t test = 4.90; P < 0.05).

REPRODUCTIVE BIOLOGY. Of the 117 adult female *E. m. krefftii* examined with a laparoscope, only four (3.54%) were preparing to breed, or breeding for the first time. The average SCL of these recruits to the adult population was 23.40 ± 1.13cm (range 22.26 to 24.96 cm).

With regard to seasonal patterns, all 27 females examined in May (8), July (5), or August (14), had bred in the previous season and were in vitellogenesis for the next season. During September the majority of females examined (21 of 30) were carrying oviducal eggs, and laparoscopic examination of the remainder indicated that they were in late vitellogenesis with approximately mature ovarian follicles in preparation for their first clutch for the season. Similarly in October most turtles examined were carrying oviducal eggs (22 of 36). A laparoscopic examination of five of this October group revealed one to be carrying her first clutch for the season, while two were carrying their second clutch for the season. Seven other females examined in October that were not carrying oviducal eggs were in late vitellogenesis and were yet to ovulate their first clutch for the season. During November four of the 14 turtles examined were carrying oviducal eggs, one was not breeding for that season and nine had ovulated at least one clutch and were carrying sufficient mature follicles for an additional clutch of eggs for the season. In December, all six of the females examined had laid at least one clutch for the season, and each had sufficient follicles to lay an additional clutch. In January and February all of the 18 turtles examined (10 in January and 8 in February) had completed egg laying for the season, and 17 had not yet begun vitellogenesis for the next season. Additionally, all 19 turtles caught outside of the breeding season (July and August) had ovarian scars consistent with having bred in previous season and had ovaries containing large developing follicles. Hence these 19 turtles were all breeding in two consecutive seasons. Thus *E. m. krefftii* in this section of the Burnett River Catchment breed seasonally, with the nesting season occurring between late spring through until mid summer. While our laparoscope data indicate that most turtles are

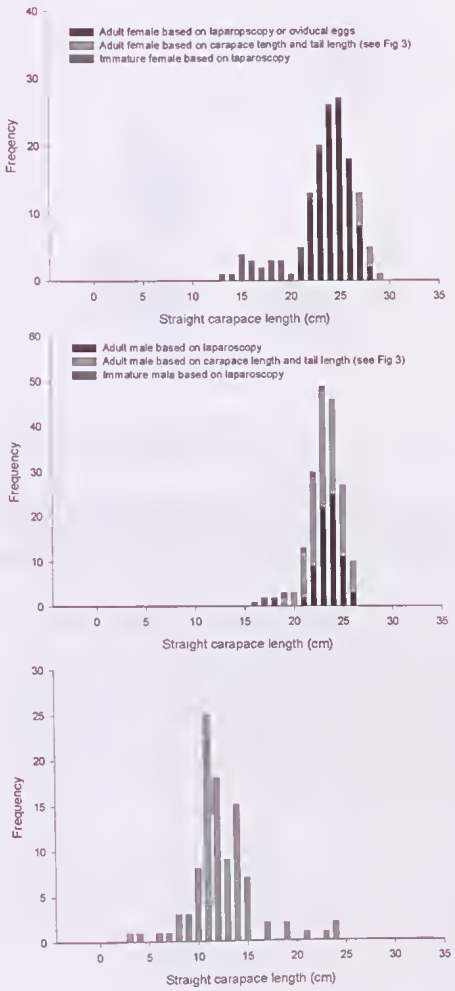

FIG. 2. Distribution of maturity ratio by 1cm increments of size for *Emydura macquarii krefftii* A, female, B, male and C, turtles that were not assessed for sex and maturity from the Paradise Dam area of the Burnett River.

capable of laying more than one clutch of eggs in a season, neither the total number of clutches laid per female or the number of eggs per clutch was determined in our study. 116 of the 117 adult females examined bred in the current breeding season. Approximately 100% of adult females bred in successive seasons.

During this study 74 adult male *E. m. krefftii* (plus one caught and examined twice at different times of the year) were examined using a laparoscope to identify their breeding status. 59 of the 60 male turtles examined between July and November (5 in July, 20 in August, 9 in September, 15 in October, 11 in November) had a large

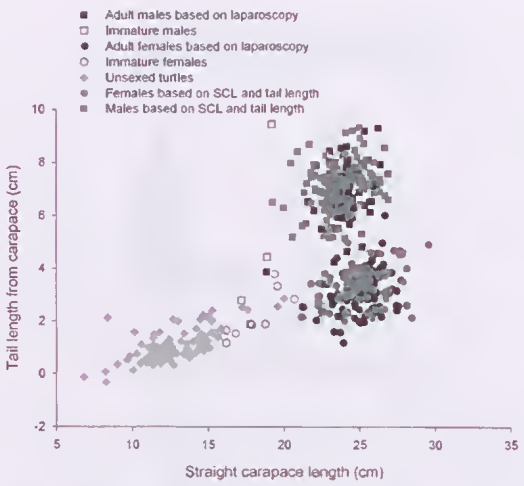

FIG. 3. Relationship between tail length from carapace and straight carapace length for *Emydura macquarii krefftii* in the Paradise Dam area of the Burnett River.

pendulous epididymus with a distended white duct indicating that they were in spermatogenesis for the up-coming breeding season. During December only three out of five turtles examined were in active spermatogenesis, and in January all 10 turtles examined had a pendulous epididymus with no distended white duct and were thus in a quiescent state. Males are seasonally spermatogenic. The male spermatogenic cycle is in synchrony with the female reproductive cycle. Based on mid year samples (July to October) 97% of adult males were in preparation for breeding for the year.

SITE FIDELITY. There were 30 short term (< six months) and 21 long term (> six months) recaptures of *E. m. krefftii* prior to the closing of the wall. The short term reeaptures comprised 6 adult males, 12 adult females, 9 unsexed immature and one each of male and female pre-pubescent immature and a female pubescent immature. These turtles were recaptured between 11 and 92 days after their initial eapture, and recaptures of all of these individuals oceurred within the same pool as their original capture. Among the long term recaptures 12 were adult females, five were unsexed immature, three were female pre-pubescent immature and one was an adult male. These turtles were recaptured between 238 and 1787 days after their initial capture. While 20 of the long term recaptured animals were eaught in the same pool as their initial capture, an adult female (tag 24311) was initially captured at Paradise and then recaptured four kilometres downstream at the Paradise Dam site.

GROWTH. Individual growth rates were analysed for the turtles recaptured over periods greater than six months. The average length of time between captures for the 12 adult females was 1135 ± 584 days. Over this period the average change in SCL was 0.48 ± 0.49cm (range 0.02 to 1.58cm). The average length of time between captures for the immature turtles was 343 ± 108 days. Over this period the average change in SCL was 1.60 ± 1.61cm (range -0.12 to 4.02cm). Only two unsexed immature turtles had recognisable hatchling scale and carapace growth layers; these turtles were within their fourth (SCL = 13.58cm) and sixth (SCL = 13.94cm) year of growth.

TABLE 2. Measurements of adult *Emydura macquarii krefftii* from the Paradise Dam area of the Burnett River.

	Adult female				Adult male			
Measurement	mean	SD	range	n	mean	SD	range	n
Straight carapace length (cm)	25.17	1.69	21.20–29.55	113	23.98	1.22	18.82–26.89	73
Straight carapace width (cm)	18.98	1.26	15.38–22.17	88	17.68	0.79	14.60–20.04	48
Plastron length (cm)	20.62	1.29	17.40–23.98	101	19.41	0.80	15.32–24.40	48
Plastron width (cm)	9.59	0.65	8.17–10.72	85	8.78	0.45	7.10–10.14	48
Head length (cm)	5.69	0.52	4.51–6.92	77	5.18	0.45	3.58–6.57	26
Head width (cm	4.04	0.40	3.31–4.90	64	3.55	0.28	1.94–4.26	26
Tail length from carapace (cm)	3.17	0.81	1.17–4.97	103	6.90	1.05	3.87–9.33	73
Tail length from plastron (cm)	7.22	1.05	5.54–9.30	61	11.10	1.02	8.38–13.89	26
Tail length from vent (cm)	3.84	0.71	2.21–5.56	61	4.96	0.95	3.40–8.38	26
Weight (kg)	1.97	0.39	1.08–3.02	113	1.54	0.23	0.70–2.35	72

SCUTE COUNTS. Scute counts were conducted on 408 individuals. While most turtles had a scute count of one nuchal scute, 4 costal scutes (left and right), 5 vertebral scutes and 12 marginal scutes (left and right), 46 (11 .3%) individuals had a non standard scute count (Table 3).

DAMAGE. Of the 534 *E. m. krefftii,* 471 were checked for external damage upon capture. Of these 57 (12.1 %) were damaged; 43 turtles with carapace damage, 1 with eye damage, 3 with small holes in a marginal scute, 8 with a single limb missing and 2 with plastron damage. For the turtles with carapace damage 41 were scored for severity; 18 had damage to a single marginal scute, 12 had damage that crossed two scutes and 11 had damage that crossed three or more scutes. All damage to these turtles was restricted to the marginal scutes. There were no turtles with large compressed fractures or fractures across the costal or vertebral areas of the carapace or the bridge between the carapace and plastron.

Elseya albagula Thomson, Georges & Limpus, 2006

POPULATION CHARACTERISTICS. In this study 21 *E. albagula* occurred across the entire study area and were caught at five of the six sites. Most individuals were caught while snorkelling (Table 1). The size class distribution by sex (Fig. 4) of captured *E. albagula* indicates that there is a low frequency of the younger age classes — 17 were adult and 4 immature. Among the adults the sex ratio was nine females to eight males. Two of the four immature turtles were sexed by laparoscopic examination which identified one of each sex.

MORPHOLOGY. Adult females were larger than adult males in all aspects except tail measurements (Table 4). SCL of immature turtles ranged from 11.21cm to 28.32cm for the immature female. Although immature animals of both sexes had similar length tails for the same SCL, in adults the relationship between SCL and tail length was a reliable external measure of sex in adult turtles (Hamann et al., 2004). Of the 17 adults, the gender and maturity of two males and six females were based upon laparoscopic examination, or palpation for eggs. The remainder of classifications were based on tail and carapace measurements. There were no significant differences between SCL (female t test = 1.91, P > 0.05; male t test = 1.24, P > 0.05) or weight (female t test = 2.81, P > 0.05; male t test = 0.38, P > 0.05) between adult male and female *E. albagula* caught in this study compared with those caught downstream in the Burnett River prior to the construction of the Ned Churchward Weir (Limpus et al., 2002).

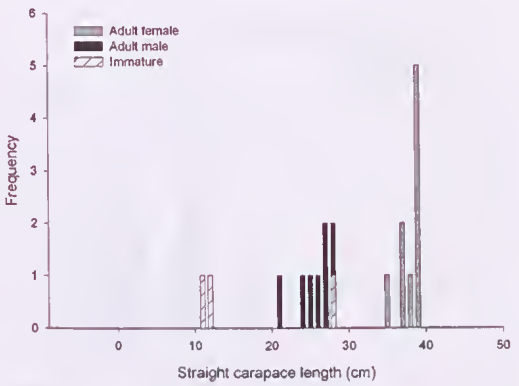

FIG. 4. Frequency distribution by size of *Elseya albagula* from the Paradise Dam area of the Burnett River.

REPRODUCTIVE BIOLOGY. Six of the nine adult female *E. albagula* caught had their reproductive status assessed by laparoscopy. All six of these females had small corpora albicantia on the ovary indicating that they had bred in a

TABLE 3. Scute counts for turtles caught in the Paradise Dam area of the Burnett River.

Scute	Scute count	Frequency			
		E. m. krefftii	*E. albagula*	*W. latistermum*	*C. expansa*
Nuchal	0	15	19	29	0
	1	393	0	5	4
Vertebral	4	1	0	0	0
	5	405	19	34	0
	6	2	0	0	3
	7	0	0	0	1
Costals	3/5	1	0	0	0
	4/4	399	19	34	4
	4/5	4	0	0	0
	5/4	1	0	0	0
	5/5	1	0	0	0
	4/6	1	0	0	0
	6/5	1	0	0	0
Marginals	11/13	1	0	0	0
	11/11	5	0	2	0
	11/12	1	0	0	0
	12/12	389	18	32	4
	12/13	5	0	0	0
	13/12	4	0	0	0
	13/13	3	1	0	0

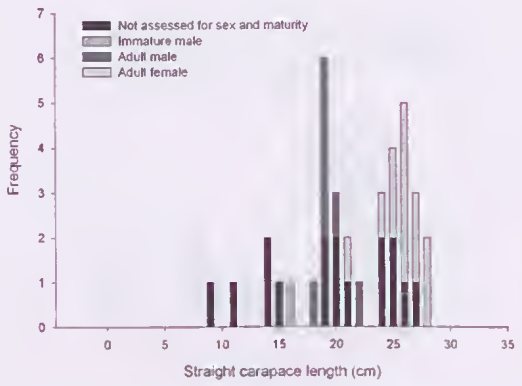

FIG. 5. Frequency distribution by size of *Wollumbinia latisternum* from the Paradise Dam area of the Burnett River.

previous season (five caught in October and one in November); all six of these turtles had one size class of large regressing corpora lutea on a vascular ovary, and small enlarged vascularised follicles. Each of these turtles had laid a single clutch of eggs within the previous few months, and were in early vitellogenesis for the next breeding season. Hence these six females were breeding in consecutive seasons. This data indicates a winter breeding season for female *E. albagula* in this area of the Burnett River Catchment.

Two adult male *E. albagula* had their maturity confirmed by laparoscopy: one caught in May 2003 was not assessed for breeding status, while the second, caught in August 2003 was in spermatogenesis.

Searches during May to September for evidence of turtle nesting, detected 22 clutches that had been recently destroyed by predators. Measurements of the length of eggshells were taken from six of the predated clutches identified 4 as *E. albagula* (mean shell length = 5.31cm ± 0.30 (range 4.86–5.75) and 2 nests as *C. expansa*. For 16 nests it was not possible to get diagnostic measurements from the egg shells. In most cases the predator(s) responsible could not be identified. However, broken *E. albagula* eggshells were found in goanna (*Varanus* species) faeces.

The *E. albagula* clutches were laid an average of 5.00 ± 4.08m (range 1.0–9.9m) from the water's edge, generally at the top of steep sloping banks (mean bank slope 54° ± 20°) and at a height of 3.20 ± 1.86m above the water level. Nesting habitat for *E. albagula* varied greatly. Soil type ranged from loose, light coloured sand, to sandy loam and compact dark soil. Three nests were found at a site underneath a closed *Casuarina* sp. canopy, and one nest was in a clear area on a sand bank. These nesting sites in the Goodnight Scrub National Park are within the area that will be flooded by the Paradise Dam. The 16 unconfirmed nests could have been from either of the winter nesting species, *E. albagula* or *C. expansa*. No decisive evidence of *E. albagula* nests was found within one km either side of the proposed site of the Paradise Dam wall.

In the area downstream of Gahans Road crossing a small sand island (~AMTD 163; 25.3941°S 151.6995°E) with an elevation between three and four metres above water level had several tracks presumably those of nesting females in May and June 2003. Despite being visited on three occasions no intact or predated clutches, and no nesting females were found to confirm whether the island is being used for nesting by *E. albagula* and/or *Chelodina expansa*. Tracks of terrestrial

TABLE 4. Measurements of adult *Elseya albagula* from the Paradise Dam area of the Burnett River.

	Adult female				Adult male			
Measurement	mean	SD	range	n	mean	SD	range	n
Straight carapace length (cm)	38.59	1.35	35.79–39.89	8	26.20	2.35	21.22–28.34	8
Straight carapace width (cm)	31.41	2.54	29.30–37.52	9	21.51	0.85	20.26–22.52	7
Plastron length (cm)	31.87	1.03	29.53–33.10	9	21.09	1.67	17.77–22.64	8
Plastron width (cm)	14.68	0.70	13.04–15.17	9	9.63	0.54	8.92–10.34	7
Head length (cm)	9.81	0.24	9.37–10.27	9	6.66	0.32	6.05–7.08	8
Head width (cm	6.60	0.41	5.60–7.07	9	4.55	0.12	4.36–4.70	7
Tail length from carapace (cm)	2.52	0.57	1.76–3.44	9	8.53	0.94	7.05–9.87	7
Tail length from plastron (cm)	9.85	0.91	8.72–11.20	9	13.61	1.00	11.90–14.96	7
Tail length from vent (cm)	6.77	0.57	5.86–7.72	9	6.94	0.79	5.89–8.00	7
Weight (kg)	7.39	0.78	6.25–8.90	9	2.25	0.59	1.04–2.85	8

predators such as foxes, cats, and goannas were not seen on the island during any visit. This island is within the area to be flooded by the Paradise Dam.

SCUTE COUNTS. Scute counts were made on 19 turtles. Most turtles had a scute count of zero nuchal scutes, 4 pairs of costal scutes, 5 vertebral scutes and 12 pairs of marginal scutes. One (5.3%) turtle had a non-standard scute count, with 13 marginal scutes on either side (Table 3).

DAMAGE. Nineteen of the 21 *E. albagula* caught were assessed for damage. Eighteen had no signs of external damage to their limbs, carapace, plastron or head; one had minor damage to a single marginal scute.

Wollumbinia latisternum (Gray 1867)

POPULATION CHARACTERISTICS. A total of 35 *W. latisternum* were caught over four of the six sites and one individual was killed by dam construction activities. Most individuals were caught by trapping (Table 1). Of the 36 individuals caught, 20 were examined by laparoscope for sex and maturity. Of these 20, 19 were adults (12 females and 7 males) and 1 was an immature male. An additional 11 individuals were of adult size but not assessed for maturity, and five immature turtles were too small for laparoscopic examination. The size class distribution by sex (Fig. 5) of captured *W. latisternum* indicates that there is a low frequency of individuals among the younger age classes.

MORPHOLOGY. Adult females were larger than adult males in all aspects except tail measurements (Table 5). The pubescent male was 16.23cm in SCL. The immature turtles ranged in SCL from 9.87cm to 15.13cm.

REPRODUCTIVE BIOLOGY. Ten of the 12 adult female *W. latisternum* had their reproductive status assessed by laparoscopy, dissection or palpation. In May each of the two females had small regressing corpora lutea on the ovarian stroma, and small, 2–3mm, developing vascularised follicles in the ovary. This indicates that they had recently completed a breeding season and were in vitellogenesis for the upcoming breeding season. Similarly, in June and August each of the five females had small regressing corpora lutea and an ovary containing large developing vascularised follicles, indicating that they had bred in the previous season and were in advanced vitellogenesis for the upcoming season. Hence all seven of the females assessed between May and August bred in two consecutive years. There were two adult females caught in November and one in December; these three females were carrying hard shelled eggs in the oviduct, had one size class of corpora lutea and no large developing ovarian follicles. Hence these three females had ovulated a single clutch for the season and did not have sufficient follicles for a second. Furthermore these data suggest that adult female *W. latisternum* have a vitellogenic period of at least five months prior to a summer nesting season. All ten females examined had corpora albicantia on the ovary indicating that they had bred in previous seasons.

Seven adult male *W. latisternum* had their reproductive status assessed by laparoscopy. A single turtle examined in May was not in spermatogenesis, while another single individual in August was. In November, of two males one was

TABLE 5. Measurements of adult *Wollumbinia latisternum* from the Paradise Dam area of the Burnett River.

	Adult female				Adult male			
Measurement	mean	SD	range	n	mean	SD	range	n
Straight carapace length (cm)	26.23	1.93	21.37–28.79	12	19.93	1.23	18.27–22.11	7
Straight carapace width (cm)	21.81	1.49	17.96–23.43	11	16.39	0.94	15.13–17.98	7
Plastron length (cm)	21.71	1.36	18.22–23.13	11	16.31	0.73	15.43–17.77	7
Plastron width (cm)	11.74	0.73	9.96–12.54	11	8.70	0.47	8.00–9.55	7
Head length (cm)	7.95	0.54	6.52–8.55	10	5.83	0.51	5.20–6.52	7
Head width (cm	5.72	0.41	4.71–6.16	10	3.99	0.34	3.56–4.50	7
Tail length from carapace (cm)	2.13	1.97	0.18–3.59	10	5.52	0.28	4.88–6.67	7
Tail length from plastron (cm)	6.54	1.25	4.12–7.96	10	8.54	0.23	8.17–9.53	7
Tail length from vent (cm)	4.04	1.09	1.25–5.07	10	3.58	0.34	3.17–4.15	7
Weight (kg)	2.54	0.49	1.37–3.29	11	0.94	0.18	0.74–1.31	7

in spermatogenesis and one was not. In January, of three males two were in spermatogenesis and one was not. The small sample size of adult male *W. latisternum* examined by laparoscopy precludes generalisations about the male reproductive cycle, other than to speculate that not all adult males breed in any one year.

SITE FIDELITY AND GROWTH. Only one *W. latisternum* was recaptured at an interval greater than six months; a pubescent male that was re-caught 370 days later in the same pool as its original capture. This turtle had grown 0.96cm over the intervening period. In addition, four of the unsexed immature turtles had recognisable hatchling scale and carapace growth layers. Assuming one growth layer equates to one year of growth (Hamann et al., 2004), these turtles were 11.5cm SCL at 2 years old, 9.87cm SCL at 4 years old, 14.65cm SCL at 5 years old, and 15.13cm SCL at nine years old.

SCUTE COUNTS. Scute counts were made on 34 individual *W. latisternum*. Most turtles had a scute count of: 0 nuchal scute, 4 pairs of costal scutes, 5 vertebral scutes and 12 pairs of marginal scutes; however seven (23.3%) had a non-standard scute count. The seven turtles with abnormal scute counts comprised five turtles with one nuchal scute and two turtles with 11 marginal scutes on one side (Table 3).

DAMAGE. Thirty of the 33 *W. latisternum* caught were assessed for damage. 28 turtles had no signs of external damage to the carapace, plastron, limbs or head. Two turtles had minor damage to the carapace and plastron respectively.

Chelodina expansa (Gray 1857)

Four *C. expansa* were caught within the study area. Two were adult males (SCLs of 25.84 and 25.04cm), one was an unsexed immature (SCL of 26.34cm), and one was classed as a male based on tail length but was not assessed for maturity. None had signs of external damage but one had an abnormal scute count (Table 3). During searches for nesting sites between July and September 2003 and 2004, two *C. expansa* nests were encountered at the Paradise Dam site. In both cases only scattered shells were found in an area with tracks and scats of goannas.

DISCUSSION

Four species of freshwater turtle (*Emydura macquarii krefftii*, *Chelodina expansa*, *Wollumbinia latisternum* and *Elseya albagula*) were caught in the area of the Burnett River that will be flooded by the Paradise Dam. *E. m. krefftii* was the most common with the other species being less frequently encountered. This pattern of species abundance is similar to that recorded in other areas of the Burnett River catchment (Tucker, 1999; Limpus et al., 2002).

While adult male *E. m. krefftii* caught in this section of the river are larger in carapace length and heavier than those caught downstream in the Burnett River prior to the construction of the Ned Churchward Weir (Limpus et al., 2002), adult females showed no significant difference. In addition, AS_{50} values for both sexes are similar between the two studies and the assessment of reproductive patterns show late spring–summer nesting and annual breeding occur in both locations. These reproductive characteristics are similar to those reported by Georges (1983) and Tucker (1999) for the same species in other locations in Queensland. Data are not available for either site that would improve analysis of reproductive patterns with respect to clutch size and within season clutch frequency.

Similarly, the morphological and reproductive data we report for adult *E. albagula* are similar to those reported on for the Burnett River prior to the construction of the Ned Churchward Weir (Limpus et al., 2002) and for the broader Burnett River Catchment (Hamann et al., 2004). Additionally, comparisons of reproductive data from throughout the catchment indicate that *E. albagula* breeds at similar times of the year (winter) and most females are breeding annually.

Frequency distributions for three of the four species caught are positively skewed towards adults, indicating a shortage of animals in the smaller size (~ equals younger age) classes. Indeed for *E. m. krefftii*, *W. latisternum* and *E. albagula* only 23%, 18% and 19% respectively of the turtles caught, were classed as immature. These size frequencies for each species are similar to those reported pre-construction in the Ned Churchward Weir (formerly Walla Weir) area (Limpus et al., 2002) and for the broader Burnett River Catchment (Tucker, 1999; Hamann et al., 2004). It is unlikely that these frequencies result from low reproductive output from females or are an artefact of capture methods. Low

reproductive output is unlikely because in our study and previous studies within the catchment almost all adult females caught in each species have been found to breed annually. It is not likely to result from size related bias in catch methods because; the same methods have been used, and in many cases the same personnel, to successfully catch turtles of all size ranges in other locations (e.g. Albert River, SE Qld, and Waruma Dam, Burnett River (QPWS unpublished data)) and at the three sites where most effort was employed a variety of sampling methods were used at multiple times of the year across multiple microhabitats.

In addition, in this study we caught low numbers of pubescent immature turtles and four adults breeding for the first time for *E. m. kreffiii*, and none for *W. latisternum* and *E. albagula*. Although, we have small sample sizes for two of these species, when our data is compared and combined with data from previous studies in the Burnett River a similar trend is found (Tucker, 1999; Limpus et al., 2002; Hamann et al., 2004). Hence, in the section of river we report on here, and in the broader Burnett River Catchment each of these three species have low numbers of individuals in immature size classes and low recruitment to adult status compared to the numbers of adult turtles that have bred over multiple seasons.

Freshwater turtle populations that are not functioning well are characterised by positively or negatively skewed size or age class frequency classes (Congdon et al., 1993; Spinks et al., 2003). Indeed the population structure of turtles that we found within this study is similar to the structure in populations of freshwater turtles that have been impacted by widespread and long running egg mortality elsewhere in Australia (Thompson, 1983; Flakus, 2002). Our data, and those of previous studies, indicate that the populations of freshwater turtles within both the area to be flooded by the Paradise Dam and in the broader Burnett River Catchment have low survival of eggs or hatchlings. Moreover, because there is a bias towards adult sized turtles in the populations we suggest these aspects have occurred over a long time frame within the catchment, and have ultimately led to a population bias towards adult sized turtles.

Despite extensive sampling effort over 500 metres either side of the site of the dam wall, that included the draining of an entire pool of water at the wall site, we only found a single *E. albagula* individual. Moreover we only caught one turtle at the study site below the wall site (Campbell's property). Hence in this area of the Burnett River, *E. albagula* occurs at very low densities and our data will provide a useful baseline from which to compare future densities at this site following the construction of the dam. This is interesting because in the years following the construction of the Ned Churchward Weir, surveys have revealed that large numbers of *E. albagula* reside in the pools immediately downstream of the weir wall (Hamann et al., 2004). It is not possible to estimate whether these aggregations occurred pre-construction because the Limpus et al. (2002) study did not sample the area downstream of where the wall was constructed.

Since the studies by Limpus et al. (2002) and Tucker (1999) an additional threat has been documented to freshwater turtles within the Burnett River Catchment, namely a higher incidence of damage to individuals residing in and around plunge pools of impoundments Hamann et al. (2004) reports that damage to turtles occurs in varying degrees from small single scute fractures to lethal multiple scute fractures that expose internal organs, and does not seem to be species or size class specific. In particular turtles residing in pools on the downstream side of impoundment walls had higher incidence of damage than those turtles inhabiting free flowing sections of river. Our study of 520 turtles occurring immediately downstream of the impoundment wall recorded only minor damage to marginal scutes of 60 individuals. This incidence is substantially lower than Hamann et al. (2004) report for turtles residing downstream of Ned Churchward and Bucca Weirs, and similar to those figures reported for other un-impounded sections of river such as Barambah Creek and Electra. Therefore, our data will serve as a useful baseline figure from which to compare the future impact of the Paradise Dam on the health and condition of the turtles of the system.

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A KEY TO THE MICROHYLID FROGS OF AUSTRALIA, AND NEW DISTRIBUTIONAL DATA

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The frog family Microhylidae is represented in Australia by *Cophixalus* (14 species) and *Austrochaperina* (5 species). The majority of these species have small rainforest distributions in north-east Queensland, primarily at higher altitude. Research on Australian microhylid frogs is increasing due to recognition of their importance in assessments of biodiversity and evolutionary history of rainforest areas, and due to their predicted susceptibility to global climate change. Accurate species identification is therefore imperative. Most of the Australian species are morphologically very similar, making identification (even between the two genera) difficult. A key to identify all 19 Australian microhylid species is provided, based on a combination of morphology, colour and pattern, calls, and distributions. The key is suitable for use in the field as well as for preserved specimens. Distributional data incorporating new records from recent fieldwork is also presented. □ *Microhylidae, distribution, key, Cophixalus, Austrochaperina, Australia, Wet Tropics.*

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The frog family Microhylidae is distributed on all continents except Antarctica (Zug et al., 2001). In Australia the family is represented by two genera, *Cophixalus* (14 species) and *Austrochaperina* (5 species), and comprises a relatively small component of the frog fauna (Hoskin, 2004). All the species are restricted to north-east Queensland and the northern tip of the Northern Territory, the majority being endemic to the 'Wet Tropics' region of north-east Queensland (between Townsville and Cooktown) where they account for >50% of the rainforest frog diversity (Hoskin, 2004). Twelve of the 14 *Cophixalus* species have very small distributions and six of these are restricted to high altitude (>700m) mountaintops (Hoskin, 2004). Most Australian microhylid frogs are restricted to rainforest, a few species also occur in sclerophyll forest, and two species are restricted to boulder fields (Zweifel, 1985; Hoskin, 2004).

Identification of the Australian microhylid species is notoriously difficult due to their small size, generally conservative morphology and cryptic habits. A key was constructed by Zweifel (1985) but it includes traits that are hard to determine in the field and does not incorporate recently described species (Richards et al., 1994; Davies & McDonald, 1998; Hoskin, 2004) or new morphological, distributional and call data (Hoskin, 2004; Hoskin & Higgie, 2005). Here I present a key for all 19 Australian microhylid frog species based on a combination of morphology, pattern/colour, distribution and call data. This data comes from Zweifel (1985), Hoskin (2004), Davies & McDonald (1998), and unpublished data I have collected. *Cophixalus crepitans* and *C. peninsularis* are not distinguished from each other in the key due to the lack of suitable characters and uncertainty over whether these two are in fact distinct species (Hoskin, 2004).

The key is suitable for identifying both live individuals in the field and museum specimens, and requires callipers or a ruler and magnification using a hand-lens, microscope or digital camera. It is of greatest value for identifying live adult males which, due to their calling activity, are the most commonly encountered and easily identified individuals. Snout to vent length (SVL) is measured from the tip of the snout to the vent (with the frog held flat), and the categories defined for species incorporate the bulk of adults measured. Some species are included twice in the key to allow for difficulty in scoring characters or in determining the appropriate size (SVL) category. Colour and pattern traits are generally less distinct in preserved specimens and some of the colour traits are only suitable for live animals (these are pointed out). All photos are of preserved specimens and Queensland Museum registration numbers (QMJ) are presented where applicable. All photos of hands are of the underneath and the fingers are numbered one to four from innermost to outermost.

The male call of each species is described in the key; for details of the calls (including spectrograms, characteristics and variation within species) refer to

Hoskin (2004). The CD by Stewart (1998) includes calls of many of these species. It should be noted that the calls of some species (e.g. *Cophixalus hosmeri*, *C. neglectus* and *C. ornatus*) can be different to those presented on the CD due to high levels of intra-specific call variation (Hoskin, 2004). It should also be noted that the call presented for *C. concinnus* on the CD is that of *C. aenigma* (Hoskin, 2004). Descriptions of distribution in the key are approximate, for details see Hoskin (2004). In addition, recent fieldwork has further clarified the distribution of some species. *C. bombiens* is now confirmed (by call, morphology and genetic data) to be present at Mossman Gorge (16°28'25"S, 145°19'49"E, 100m elevation, 16/1/05), a significant southerly range extension. The lower altitudinal limit of *C. concinnus* has been estimated in the field to be 1080m (Hoskin & Higgie, 2005), which is similar to the estimate of 1100m based on museum specimen data (Hoskin, 2004). I recently found *C. neglectus* calling at 975m elevation on Mt Bartle Frere (17°22'39"S, 145°47'12"E, 26/1/05). This is similar to the lower altitudinal limit of 900m reported by Zweifel (1985) and McDonald (1992), but differs from the lower elevational limits recorded on recent altitudinal surveys of Mt Bartle Frere (1150m, Hoskin, 2004; 1340m, Shoo & Williams, 2004) and Mt Bellenden Ker (1200m, Shoo & Williams, 2004; 1230m, this paper, 17°15'51"S, 145°51'52"E, 20/1/05). Although the 975m record suggests a lower altitudinal limit for *C. neglectus* than has been recently recognised, it should be noted that it is based on a small chorus of males that were calling in a deep rock pile at considerably lower elevation than the nearest other males found calling on that night, which were at 1125m elevation (17°22'45"S, 145°47'24"E, 26/1/05).

Cophixalus and *Austrochaperina* can be distinguished from other rainforest frogs in northern Australia (except *Taudactylus*) by the absence of webbing between the toes. From *Taudactylus* they can be distinguished by lacking barring on the legs and by lacking prominent, rounded tubercles on the underside of the hands. Cogger (2000) provides additional characters for distinguishing the microhylid frogs from other Australian frogs.

KEY TO AUSTRALIAN MICROHYLID FROGS (*COPHIXALUS* AND *AUSTROCHAPERINA*)

1. Small to medium body size (SVL 18–47mm) 2
   Very small body size (SVL 12–18mm)..... 16

2. Finger discs obviously expanded from finger width (although disc on first finger very small) (e.g. Figs 1A–B)..... 3
   Finger discs not obviously expanded (e.g. Figs 1C–D) 10

3. Third finger disc obviously wider than disc of fourth toe, and more truncate than rounded (e.g. Figs 1A, 1E)..... 4
   Third finger disc about the same width as, or narrower than, disc of fourth toe, and more rounded than truncate (e.g. Fig. 1B) 7

4. Ventral pattern (particularly throat and chest) of dark blotches on a red (in life) and white background (Fig. 1F); call a short trill/creak; >1100m Thornton Peak ..... *C. concinnus*
   No obvious dark blotching or red on ventral surfaces, instead, evenly pale, yellow or grey, or finely spotted with grey or brown..... 5

5. SVL 18–28mm; dorsal pattern of dark and cream markings on a pale grey or brown background; call a short 'beep'; widespread in southern and central Wet Tropics, between Carbine Tableland and Paluma ..... *C. ornatus*
   SVL >29mm 6

6. SVL 29–47mm; axilla and groin orange or yellow (in life), female dorsum yellow (in life) or pale (in preservative), males mottled grey or brown; call a slow tapping; boulder fields of Black Trevethan Range ..... *C. saxatilis*
   SVL 40–46mm (female); axilla and groin scarlet (in life), female dorsum tan with brown speckles, male unknown; call unknown; boulder fields of Cape Melville ..... *C. zweifeli*

7. Found south of Cairns..... 8
   Found north of Cairns 9

8. Prominent black dorsolateral dash above forelimb; fingers long; call a short trill/creak; >900m Mt Elliot ..... *C. mcdonaldi*
   Dorsolateral surface may be blotched or smudged brown, but no prominent black dorsolateral dash above forelimb; fingers short; call a short buzz or squeich; >1000m Mt Bartle Frere and Mt Bellenden Ker..... *C. neglectus*

9. Call a short trill/creak; generally calls from elevated position; >1100m Carbine Tableland..... *C. monticola*
   Call a slow or medium-paced tapping; generally calls from ground or close to it; >700m Carbine and Thornton Uplands and Mt Finnigan..... *C. aenigma*

10. First finger about half length of second (e.g. Fig. 1C) 11
    First finger short, obviously less than half length of second (e.g. Fig. 1D) 15

11. Found north of Cooktown or in Northern Territory; SVL <21mm..... 12
    Found south of Cooktown; SVL >21mm 13

12. Found on northern tip of Northern Territory and associated offshore islands; call a series of peeps uttered rapidly (about 40 per 10 seconds) ..... *A. adelphe*
    Found on Cape York Peninsula north of Cooktown (also in southern PNG); call a series of peeps uttered slowly (about 15 per 10 seconds) ..... *A. gracilipes*

13. In life, a well-defined pale line extending from nostril over eye and a reddish flecked iris; in preservative, reasonably sharp demarcation from darker throat and chest to lighter abdomen; call a rapid series of high-pitched notes; widespread in the Wet Tropics .... *A. pluvialis*
    In life, no (or poorly defined) pale line extending from nostril over eye and a golden flecked iris; in preservative,

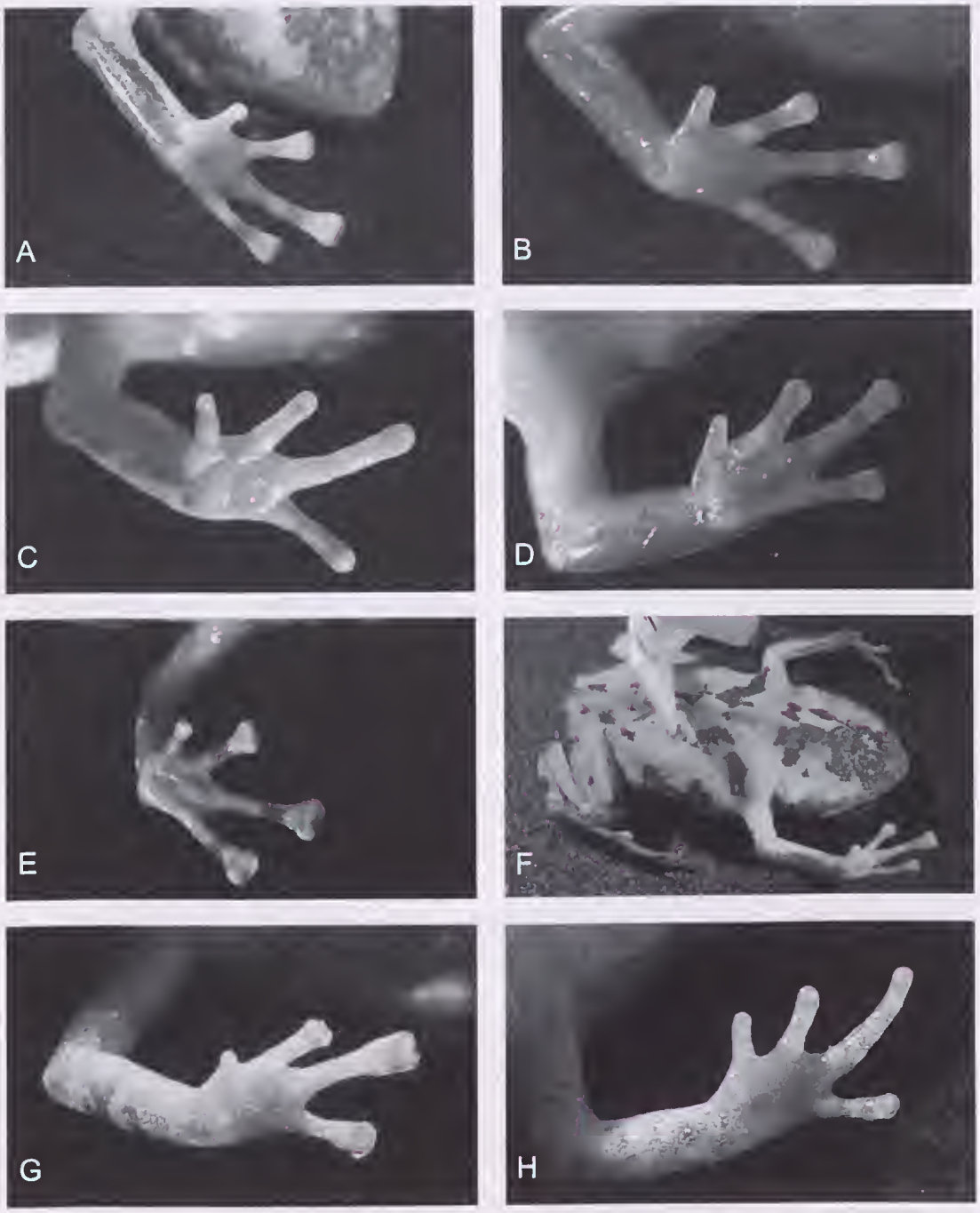

FIG. 1. A, *Cophixalus concinnus*, QMJ43917; B, *C. aenigma*, QMJ53879; C, *Austrochaperina robusta*, QMJ55888; D, *C. neglectus*, QMJ55795; E, *C. ornatus*, Mt Bartle Frere; F, *C. concinnus*, QMJ43917; G, *C. crepitans*, QMJ28817; H, *Austrochaperina gracilipes*, QMJ70512.

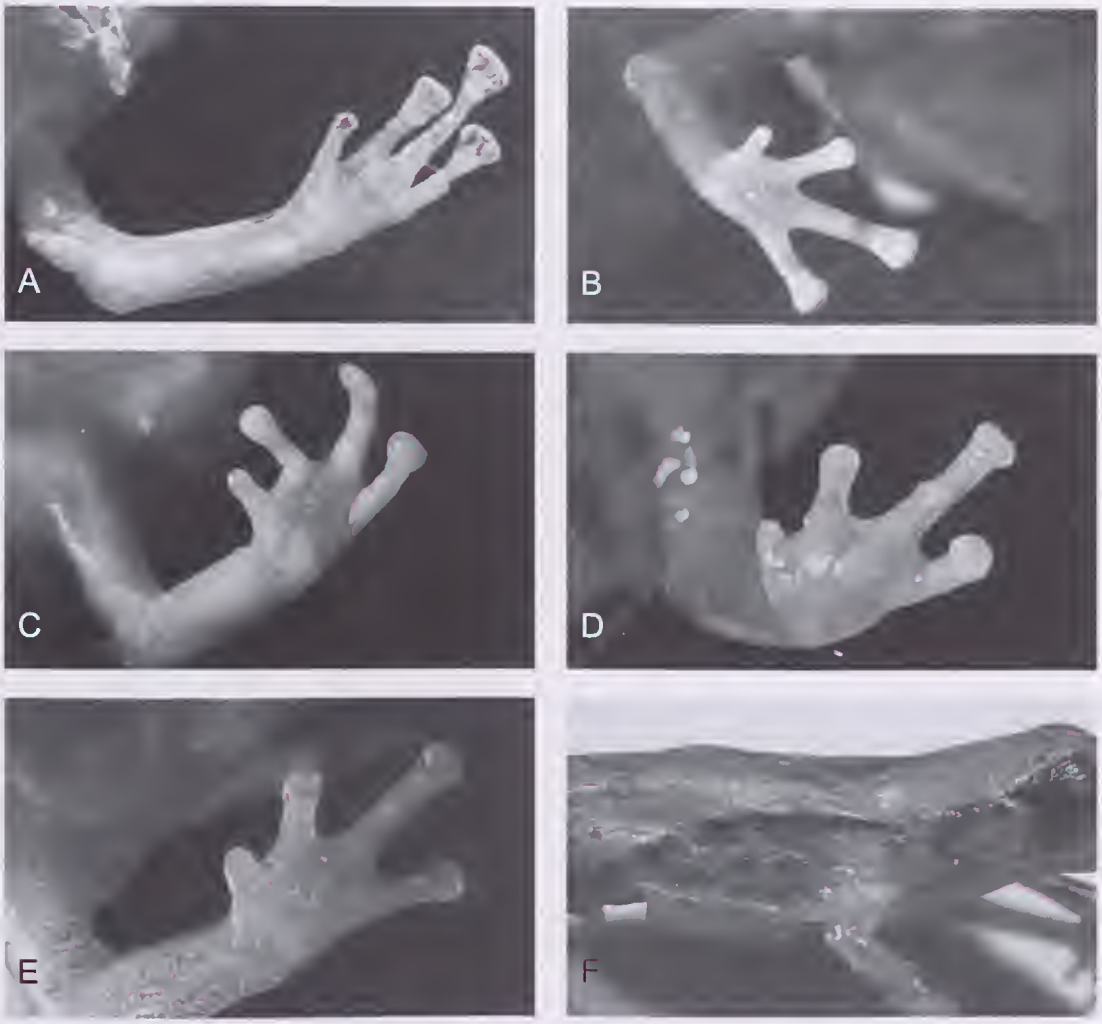

FIG 2. A, *Cophixalus ornatus*, Tully Valley; B, *C. infacetus*, QMJ39897; C, *C. exiguus*, QMJ40596. D, *C. bombiens*, QMJ55993; E, *C. hosmeri*, QMJ56467; D, *C. bombiens*, Windsor Tbld.

gradual transition from darker throat and chest to lighter abdomen; call a series of brief, high-pitched whistles or whistle-like couplets. 14

14. Call a series of brief, high-pitched whistles/chirps, uttered as couplets (in pairs); southern half of Wet Tropics north to northern Atherton Tableland, Lamb Range and Malbon Thompson Range . . . . . *A. robusta*

Call a series of brief, high-pitched whistles/chirps; northern half of Wet Tropics south to Lamb Range and northern Atherton Tableland. . . . . *A. fryi*

15. Prominent black dorsolateral dash above forelimb; fingers long; call a short trill; >900m Mt Elliot . . . . *C. mcdonaldi*

Dorsolateral surface may be blotched or smudged brown, hut no prominent black dorsolateral dash above forelimb; fingers short; call a short buzz or squelch; >1000m Mt Bartle Frere and Mt Bellenden Ker . . . . . *C. neglectus*

16. Found north of Cooktown or in Northern Territory . . 17

Found south of Cooktown. 19

17. First finger short, obviously less than half length of second (e.g. Fig. 1G); call a short rattle, composed of paired clicks; Mellwraith Ra . . . . . *C. crepitans/C. peninsularis*

First finger about half length of second (e.g. Fig. 1H) 18

18. Found on northern tip of Northern Territory and associated offshore islands; call a series of peeps uttered rapidly (about 40 per 10 seconds). . . . . *A. adelphe*

Found on Cape York Peninsula north of Cooktown (also in southern PNG); call a series of peeps uttered slowly (about 15 per 10 seconds) . . . . . *A. gracilipes*

19. Found south of Cairns. 20

Found north of Cairns 21

20. Large, slightly truncate finger discs (Fig. 2A); SVL >17mm; call a short 'beep', this small 'form' found on Hinchinbrook Is. and lowlands (<500m) of Mt Bartle Frere, Palmerston

Valley, Tully Valley, Mission Beach..... *C. ornatus*

Distinct but small, rounded finger discs (Fig. 2B); SVL <17mm; a creaking call of finely pulsed clicks; between Cairns and Herbert River (Ingham)..... *C. infacetus*

21. First finger well formed, about half length of second (Figs 1B, 2C); male SVL >14mm..... 22

First finger a short 'nubbin', about one third length of second (Figs 2D–E); male SVL <14mm 23

22. SVL >17mm; call a slow or medium-paced tapping; >700m Carbine and Thornton Uplands and Mt Finnigan ..... *C. aenigma*

SVL <17mm; call a medium-paced tapping: Big Tableland, Mt Hartley and surrounding lower altitudes (including lower slopes of Mt Finnigan)..... *C. exiguus*

23. A broken or continuous series of prominent black dashes/blotches extending from behind the eye and down flank (e.g. Fig. 2F); call a short buzz 'bzzzip'; Windsor Tableland and scattered sites (primarily lowland) in northern Wet Tropics (e.g. Thornton Peak area, Shiptons Flat, Mossman Gorge) ..... *C. bombiens*

Flank mottled or blotched but not prominently marked with black as above; call usually a fast-paced tapping/clicking (but occasionally a medium-paced tapping or a buzz); >800m Carbine Tableland ..... *C. hosmeri*

ACKNOWLEDGEMENTS

I thank Patrick Couper for access to specimens held in the Queensland Museum, Megan Higgie and Anthony Backer for trialing the key, and Keith McDonald for suggestions that improved the key. Also, thanks to Megan Higgie, Jason MacKenzie, the Queensland Ambulance Service, the Queensland State Emergency Service, the Queensland Rescue Helicopter, and the Cairns Base Hospital for my rescue and recovery from a fall on Mt Bartle Frere while conducting fieldwork on microhylid frogs.

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FIRST RECORD OF THE ALPINE WATER SKINK, *EULAMPRUS KOSCIUSKOI* (KINGHORN, 1932) (SQUAMATA: SCINCIDAE) FROM QUEENSLAND. *Memoirs of the Queensland Museum 52(2): 238. 2008:*–Water Skinks (*Eulamprus quoyii* species group) are a lineage (O'Connor & Moritz, 2003) of moderate-sized, diurnal skinks occurring in south-eastern and eastern Australia. They are commonly located in proximity to moist environments (O'Connor & Moritz, 2003; Hutchinson & Rawlinson, 1995), and are prominent members of the herpetofaunal communities in which they occur. Only a single species, *Eulamprus quoyii* (Duméril & Bibron), has been recorded from Queensland to date (Arnold, 1967; Covacevich & Couper, 1991), although preliminary genetic studies suggest that more than one species may occur in *E. quoyii* (O'Connor & Moritz, 2003; S. Keogh, pers. comm.). The other four species in the lineage, *E. heatwolei* Wells & Wellington, *E. kosciuskoi* (Kinghorn), *E. leuraensis* Wells & Wellington and *E. tympanum* (Lönnberg & Andersson) are more southern in distribution, occurring mostly in New South Wales and Victoria.

While examining samples of *E. quoyii* in the collection of the Queensland Museum as part of a study of morphological variation in this species, we discovered two specimens, QMJ12227-12228, which we consider to be *Eulamprus kosciuskoi*. These two individuals, from Stanthorpe (presumably the town at 28°40'S 151°56'E, near the NSW border in south-east Queensland), collected by F. Boyce and donated by J. Arnold, were identified by Arnold (1967) as *E. quoyii*. Since receipt by the Queensland Museum, they had been identified as *E. kosciuskoi*, then reidentified as *E. quoyii*. There is no date of collection associated with the records, but they were presumably registered into the QM collection in the early 1960s, based on other registrations around them.

The two specimens have the following characters, scale counts and measurements (J12227 first, where differences occur between the specimens; character definitions follow Shea & Peterson, 1985): prefrontals broadly or narrowly contacting medially; supralabials 7; supraciliaries 9L/9R, 10L/9R; midbody scales 36; paravertebral scales 63; lamellae below fourth toe 24L/25R, 21L/21R; snout-vent lengths 75.5, 50.5mm; axilla-groin lengths 37.5, 23mm; forelimb lengths 18, 14mm; hindlimb lengths 28, 20.5mm; head lengths 15.5, 11.6mm; head widths 10.9, 7.7mm; head depths 8.7, 6.5mm. One of the specimens (QMJ12227) is a mature but non-reproductive female, while J12228 is a non-reproductive male.

In colouration and scalation, both specimens agree with the northern form of *Eulamprus kosciuskoi* (Shea & Peterson, 1985), and are readily differentiated from regionally sympatric populations of *E. quoyii* which have: paravertebral scales 65-77 (n = 9); subdigital lamellae 25-32 (n = 9); snout-vent length of mature individuals 82-112.5mm (n = 8); the body dorsum with scattered dark spots (vs lacking scattered spots, but with a narrow dark laterodorsal stripe, extending to the sacral region, and medial to a paler dorsolateral stripe, either of the dorsal ground colour or a paler shade); at most, a narrow, broken extension of the pale ventral colour along the anterior margin of the ear (vs a broad dorsal extension of the pale ventral colour in this position); at most, a few pale flecks longitudinally aligned from the dorsal margin of the ear along the neck to nearly above the forelimb (vs a broad pale stripe in this position); a random scattering of dark spots and flecks along the lateral side of the tail (vs dark spots aligned in multiple transverse rows), and the body venter (in preserved individuals) with a yellow tinge at least posteriorly (vs body venter completely clouded blue-grey).

The locality for these specimens is 100km NNW of the nearest previous record of *E. kosciuskoi*, from Waratah Swamp, Gibraltar Range National Park, NSW (29°30'00"S 152°19'40"E, Australian Museum R96836-37). The latter locality is itself nearly 70km NNW of the next nearest locality for the species (several Australian Museum records from Marengo State Forest).

The locality for QMJ12227-28 is not precise, just giving the town as a locality, and hence some residual doubt must remain about the veracity of the record. However, there is potentially suitable habitat for *E. kosciuskoi* in the vicinity of Stanthorpe. Northern NSW populations of *E. kosciuskoi* have been collected from subalpine button grass swamps and sphagnum bogs (GS, pers. obs.) and a series of such swamps extends north of Ebor, through Gibraltar Range and on to the Queensland border (Hunter & Bell, 2007). Moss and peat swamps are present in Girraween National Park, less than 25km south of Stanthorpe (R. Hobson, QPWS, pers. comm.), and efforts should be made to search for the species in these and other nearby sites to verify the existence of this species in Queensland.

Comparative material of *Eulamprus quoyii* examined: QMJ12223-24, J14250-51, J16403-04, J26041, J30738, J78171.

Acknowledgements

We thank P. Couper and A. Amey for the loan of the specimens and for their efforts to verify the records.

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NEW RECORDS OF A FLATHEAD FISH, *ONIGOCIA GRANDISQUAMA* (REGAN, 1908) (TELEOSTEI: PLATYCEPHALIDAE) FROM AUSTRALIA

HISASHI IMAMURA AND MARK MCGROUTHER

Imamura, H. & McGrouther, M. 2008 04 30: New records of a flathead fish, *Onigocia grandisquama* (Regan, 1908) (Teleostei: Platycephalidae) from Australia. *Memoirs of the Queensland Museum* **52**(2): 239–243. Brisbane. ISSN 0079-8835.

Thirteen specimens of a poorly known platycephalid fish, *Onigocia grandisquama* (Regan, 1908), were collected from Queensland, eastern Australia. This species can be easily separated from its congeners by having 11–12 (usually 11) anal fin rays, large head (41.1–45.3% SL), ocular flap present, iris lappet short and with multiple branches dorsally, 1–2 preocular spines, and interopercular flap absent. These specimens are the first records of the species from Australia and only the second record from the western Pacific. ❐ *Onigocia grandisquama, Platycephalidae, first record from Australia, western Pacific*

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The genus *Onigocia* Jordan & Thompson, 1914 is diagnosed by having a finely serrated suborbital ridge and usually less than 40 pored lateral line scales. Six valid species are known: *O. bimaculata* Knapp, Imamura & Sakashita, 2000, *O. grandisquama* (Regan, 1908), *O. macrolepis* (Bleeker, 1854) (type species of *Onigocia*), *O. oligolepis* (Regan, 1908), *O. pedimacula* (Regan, 1908) and *O. spinosa* (Temminek & Schlegel, 1842; Imamura, 1996; Knapp et al., 2000). The relatively rare species, *O. grandisquama*, has not previously been reported from Australian waters (e.g., Sainsbury et al., 1985; Knapp, 1999; Knapp et al., 2000). To date the species has been recorded from the following five localities: Amirante Islands (Seychelles), Mauritius, Somalia, Arabian Sea and Gulf of Thailand (Regan, 1908; Imamura & Sakashita, 1997; Knapp, 1999; Manilo & Bogorodsky, 2003).

A single specimen of *Onigocia* collected from Queensland, eastern Australia was recently found in the Ichthyology Collection at the Australian Museum. After a detailed examination, this specimen was identified as *O. grandisquama*. Subsequently it was brought to our notice that there were an additional 12 specimens of the species deposited at the Queensland Museum. These specimens are the first records of the species from Australia, and only the second record from the western Pacific.

MATERIALS AND METHODS

Counts and measurements were made following Hubbs & Lagler (1958) and were routinely taken from the left side, while gill rakers were counted on the right side. Measurements were made with calipers to the nearest 0.1mm. Head spine terminology follows Knapp et al. (2000). Standard and head lengths are abbreviated as SL and HL, respectively. Institutional acronyms follow Leviton et al. (1985), except for National History Museum and Institute, Chiba (CMNH).

Onigocia grandisquama (Regan,1908) (Figs 1–2)

Platycephalus grandisquamis Regan, 1908: 239 (original description; Amirante Islands, Seychelles, western Indian Ocean).

Onigocia grandisquamis: Matsubara & Ochiai, 1955: 71 (discussion on generic position).

Onigocia grandisquama: Imamura, 1996: 214 (discussion on generic position); Imamura & Sakashita, 1997: 119, figs 1–4 (redescription; Amirante Islands, Seychelles, western Indian Ocean and Gulf of Thailand, western Pacific); Knapp et al., 2000: 8 (list of comparative material; Amirante Islands, Mauritius and Somalia, western Indian Ocean); Manilo & Bogorodsky, 2003: S103 (list, Arabian Sea).

MATERIAL EXAMINED. AMS I.24489-005 (68.6mm SL), 4 miles east of North Reef (23°09'S, 151°58'E), 64m, 14.12.1977, W. Ponder et al.; QM I.23086 (73.1mm SL), off Swain Reefs (21°37.8'S, 151°53.8'E), 45m, 18.09.1986; QM I.23267 (64.7mm SL), near Keeper Reef (18°46.2'S, 147°12.6'E), 42m, 18.10.1985; QM I.36770 (77.5mm SL), 23°17.7'S, 151°35.7'E, 37m, 20.09.2004; QM I.36807 (63.4mm SL), 21°46.5'S, 151°50.1'E, 60m, 8.10.2004; QM I.37439 (72.9mm SL), off Swain Reefs (21°13'S, 150°43'E), 47m, 16.09.2005; QM I.37839, 5 specimens (46.8–72.9mm SL), 21°08.7'S, 152°05.1'E, 58m, 22.11.2005; QM-I37923 (64.6mm SL), 23°06.9'S,

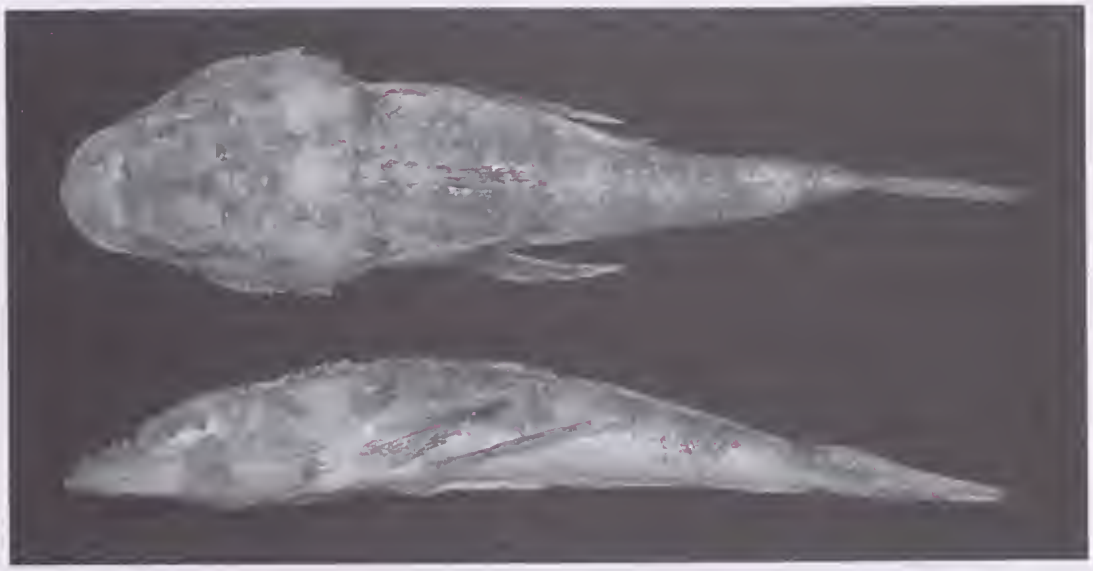

FIG. 1. Dorsal (upper) and lateral (lower) views of *Onigocia grandisquama*, QM I.36770, 77.5mm SL, collected from Queensland, eastern Australia.

151°44.7'E, 48m, 9.11.2005; QM-I40097 (66.6mm) SL, 19°26.1'S, 149°40.5'E, 74m, 26.11.2005

DIAGNOSIS. A species of *Onigocia* with 11 anal fin rays (infrequently 12), large head, ocular flap present, iris lappet short and with multiple branches dorsally, 1–2 preocular spines and no interopercular flap.

DESCRIPTION. Counts and proportional measurements are given in Table 1. Body depressed. Head flattened and broad. Snout spatulate, shorter than eye diameter. Eye with single ocular flap dorsally. Iris lappet short, with multiple branches dorsally, usually bilobed or rarely simple ventrally (Fig. 2). Interorbit narrow and concave. Head bearing many spines dorsally and laterally. Nasal with one small spine. One or two ethmoid spines present. Lachrymal with two or three (usually two) antrorse spines anteriorly. One or two (usually one) sharp preocular spines present. Suborbital ridge finely serrated. Supraorbital ridge finely serrated along entire length except for anterior region. Postorbital region with a group of one to eight (usually four to six) small spines. Pterotic with serrated ridge comprised of four to seven, or nine small spines. A single nuchal spine on supracleithrum; posttemporal and supratemporal with one to three spines, respectively. Preoperele with three spines; uppermost longest, not reaching posterior margin of operele, bearing one supplementary spine. Base of upper and lower opercular spines without serrations. Interopercular flap absent. Maxilla reaching beyond anterior margin of pupil. Villiform teeth in single bands on jaws and palatine, in two separate patches on vomer; teeth on anteromedial portion of upper jaw, palatine and posterior portion of vomer, and in innermost row of lower jaw slightly longer and rather pointed. Tooth band on upper jaw without a distinct notch anteromedially. Lip margins without papillae. Sensory tubes from suborbitals and preoperele well developed, completely covering cheek region. Pored scales in lateral line with two exterior openings posteriorly. First dorsal fin originating slightly behind opercular margin. First and second dorsal fins narrowly separated. Pectoral fin rounded posteriorly. Posterior tip of pelvic fin reaching to base of third to fifth anal fin ray. Caudal fin mostly straight or slightly rounded posteriorly.

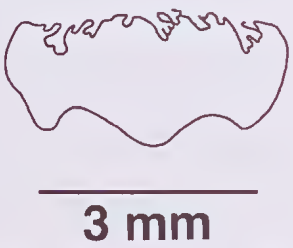

FIG. 2. Iris lappet (left eye) of *Onigocia grandisquama*, AMS I.24489-005, 68.6 mm SL, collected from Queensland, eastern Australia.

TABLE 1: Comparison of eounts and proportional measurements of *Onigocia grandisquama*.

Measurement	Present speeimens	BMNH 1908.3.23.209
Number	13	1 (holotype)
SL (mm)	46.8–77.5	54.4
Counts:		
First dorsal fin rays	I–VII–VIII (usually VIII)	I–VIII
Seeond dorsal fin rays	10–11 (usually 11)	11
Anal fin rays	11–12 (usually 11)	11
Peetoral fin rays	19–21 (often 20)	21
Pelvie fin rays	1,5	1,5
Branehed caudal fin rays (upper + lower)	4–5 + 4–5	Broken
Pored seales in lateral line (with spine)	34–39 (3–8)	32 (4)
Gill rakers	1 + 4–5 = 5–6 (usually 1 + 4 = 5)	1 + 4 = 5
Proportional measurements (% SL):		
HL	41.1–45.3	44.7
Predorsal length	39.8–42.8	42.6
Length of first dorsal fin base	18.5–23.4	20.2
Length of second dorsal fin base	22.8–27.3	24.1
Length of anal fin base	25.9–29.2	27.4
Caudal peduncle length	8.0–9.5	9.0
Caudal peduncle depth	4.9–5.8	5.1
Snout length	10.8–11.5	11.2
Orbital diameter	13.4–14.8	14.7
Upper jaw	16.2–18.0	17.6
Lower jaw	22.4–24.7	24.1
Interorbital width	1.6–2.6	2.4
Peetoral fin length	17.3–19.9	19.9
Pelvie fin length	27.9–32.3	Broken
Caudal fin length	22.8–25.5	Broken
Length of first dorsal spine	6.6–9.5	7.5
Length of seeond dorsal spine	15.0–18.3	16.5
Length of first dorsal soft ray	14.0–16.7	Broken
Length of first anal fin ray	9.2–13.1	11.8
Proportional measurements (% HL):		
Snout length	24.8–26.5	25.1
Orbital diameter	32.1–33.3	32.1
Upper jaw	38.8–40.7	39.5
Lower jaw	52.4–56.1	53.9
Interorbital width	3.6–5.8	5.3

Colour in alcohol. Head and body light brown dorsally, pale ventrally. Head with slightly darker band crossing occipital region and cheek; indistinct or somewhat distinct narrow brown band or patch below eye. Body with two broad, saddle-like, brown bands below both dorsal fins (band below second dorsal fin on left side in QM-I36770 separated into two indistinct narrower bands, see lower photograph in Fig. 1), and one brown patch on caudal peduncle (patches on both sides partially continuous). First dorsal fin with grayish or blackish band, with several unpigmented areas along spines. Second dorsal fin with several small brown spots and/or melanophores. Anal fin pale or with few brownish spots or dusky areas. Upper 1/3 of pectoral fin with melanophores or small brown spots, which tend to comprise bands; lower 2/3 dark brownish or blackish except for pale brown lower margin and basal portion. Pelvic fin dark brownish to blackish except for pale outer margin. Caudal fin margin with distinct or indistinct narrow brownish band; rest of fin with or without small brownish spots and/or melanophores.

DISTRIBUTION. Known only from Amirante Islands, Mauritius, Somalia, Arabian Sea, Gulf of Thailand and Queensland, eastern Australia (Regan, 1908; Imamura & Sakashita, 1997; Knapp, 1999; Manilo & Bogorodsky, 2003; this study).

REMARKS. The specimens of *Onigocia* collected from eastern Australia agree well with the examined holotype of *O. grandisquama* (BMNH 1908.3.23.209), in having an ocular flap, iris lappet short and with multiple branches dorsally, 1–2 ocular spines, and lacking an interopercular flap. In addition, counts and proportional measurements of specimens examined in this study are similar to those of the holotype, except for having 34–39 pored scales in the lateral line (vs. 32 in holotype of *O. grandisquama*). Knapp et al. (2000) stated that the number of the pored scales in the lateral line of *O. grandisquama* ranged from 31 to 39. We identify the present specimens as *O. grandisquama*, recognising the variation in the lateral line scales as intra-specific, as pointed out by Knapp et al. (2000). *Onigocia grandisquama* can be easily separated from other members of the genus in having the following combination of characters: usually 11anal fin rays [vs. 11–13 (usually 12) in *O. macrolepis* and 12 in *O. spinosa*], larger head (41.1–45.3% SL in *O. grandisquama* vs. 33.8–39.3% SL in *O. bimaculata*, 35.2–38.9% in *O. macrolepis* and 36.8–42.1% in *O. spinosa*), an ocular flap and iris lappet that is short and with multiple branches dorsally (usually bilobed ventrally) (vs. ocular flap absent and iris lappet bilobed, simple or crenate in all *Onigocia* except for *O. macrolepis* and *O. spinosa* which have short and multiple branches to the iris lappets), 1–2 preocular spines (vs. 3 or more in all *Onigocia* except for *O. macrolepis*, which has one spine) and lacking an interopercular flap (vs. present in *O. bimaculata*) (data from Regan, 1908; Imamura & Sakashita, 1997; Knapp, 2000; this study).

COMPARATIVE MATERIAL. Most comparative material examined was listed in Imamura & Sakashita (1997). However, their *Onigocia oligolepis* (Regan, 1908) may be an undescribed species (Knapp, pers. comm.); thus, its data were not included here. Additional comparative material is listed below:

Onigocia bimaculata (4 specimens): CMNH ZF13964 (66.6mm SL), Yakushima Island, Japan; NSMT-P 54247 (holotype, 58.6mm SL), NSMT-P 45638, P 54248, P 54249 (3 paratypes, 23.2–36.8mm SL), Ryukyu Islands, Japan.

Onigocia pedimacula (4 specimens): NSMT-P 69917 (4, 62.0–73.2mm SL), Indonesia.

Onigocia spinosa (1 specimen): AMS I.22831-013 (1 of 11, 72.8mm SL), northwestern Australia.

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SYNCLIDOPUS HOGANI, A NEW SPECIES OF SOLEID FISH FROM NORTHEASTERN QUEENSLAND, AUSTRALIA

JEFFREY W. JOHNSON AND JOHN E. RANDALL

Johnson, J.W. & Randall, J.E. 2008 04 30: *Synclidopus hogani*, a new species of soleid fish from northeastern Queensland, Australia. *Memoirs of the Queensland Museum* **52**(2): 245–254. Brisbane. ISSN 0079-8835.

Synclidopus hogani is described as a new soleid fish from the Daintree River, northeastern Queensland. It differs from its single known congener, *S. macleayanus*, in having a lower median lateral-line scale count (87-97 versus 94-113), a distinctive colouration, which includes about 22-26 highly irregular, mostly discontinuous, transverse brown bands across the head and body, and three longitudinal rows of large dark brown spots, as well as a much smaller maximum size. The new species appears to be highly restricted in distribution and prefers tidal lower freshwater reaches of the river. It has not been recorded during numerous surveys of the Daintree estuary, surrounding coastal waters, or other estuarine or freshwater systems of northeastern Queensland. *Synclidopus* Chabanaud is redefined to include an important distinguishing feature of a free fleshy sheath that covers the anterior half of the lower jaw and the lower lip on the blind side.❐ *Pleuronectiformes, Soleidae, Synclidopus, Aseraggodes, new species, freshwater, Daintree River, Queensland.*

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Randall (2005) resurrected the soleid genus *Synclidopus* Chabanaud, 1943, from the synonomy of *Aseraggodes* Kaup, recognising the distinctiveness of the type species, *S. macleayanus* (Ramsay, 1881). He distinguished *Synclidopus* from *Aseraggodes* in having: the second lateral line on the ocular side of the head continuing dorsoanteriorly on the body, a deeper body, a shorter and more obtuse head, smaller eyes, its anus and genital papilla on the blind side, a higher number of lateral-line scales (96-113 versus 53-96), 7 dorsal pterygiophores anterior to fourth neural spine (versus 7-16; only one with 7 or 8), and the distinctive colour pattern of narrow dark bars. *Synclidopus macleayanus* commonly occupies estuarine as well as inshore marine habitats, whereas the numerous species of *Aseraggodes* are known only from marine habitats (Randall, 2005).

During a long-term monitoring program in freshwaters of the Daintree River, northeastern Queensland, evaluating populations of barramundi (*Lates calcarifer*) and associated fishes, an unusual soleid fish was collected and sent to the first author for identification. The specimen was initially identified as an undescribed species of *Aseraggodes*, however, on closer examination it was found to be more closely aligned with *Synclidopus*, as defined by Randall (2005). Comparisons revealed a previously overlooked character, a well-developed free fleshy sheath that covers the anterior half of the lower jaw and the lower lip, that is unique to this species and *S. macleayanus*. *Synclidopus* is thereby redefined to include this feature, and several proportional measurements and meristic values for the genus are revised to account for the new species and smaller specimens of *S. macleayanus* than were available for the generic diagnosis of Randall (2005). We describe herein the new species based on six specimens collected from the lower freshwater reaches of the Daintree River, northeastern Queensland, and redefine *Synclidopus* in the light of the newly recognised morphological feature and increased range of meristic and morphometric values observed in specimens of the two species.

MATERIALS AND METHODS

The holotype of the new species is deposited in Queensland Museum, Brisbane (QM); paratypes are also lodged in Australian Museum, Sydney (AMS), and Bishop Museum, Honolulu (BPBM).

Standard length (SL) is measured horizontally from anterior margin of upper lip to caudal-fin base (end of hypural plate). Body depth is maximum distance between bases of dorsal and anal fins; body width is maximum

thickness midlaterally between ocular and blind surfaces (but not over abdomen). Predorsal, preanal and prepelvic lengths are point to point measurements, taken directly to snout tip. Head length (HL) is measured from anterior margin of upper lip to a vertical at fleshy posterior end of operculum. Preorbital length is the distance from front margin of upper eyeball (dark part of eye, hereafter termed only as eye) directly forward to anterior edge of head. Snout length is taken from the anterior margin of upper lip to nearest edge of upper eye. Eye diameter is the greatest diameter of lower eye (not fleshy cutaneous part). Interorbital width is the vertical distance between horizontal lines at ventral edge of upper eye and dorsal edge of lower eye. Upper-jaw length is measured on the blind side from anterior margin of upper lip to posterior edge of maxilla. Lengths of rays of median fins are measured from base of ray (not where it emerges from basal scaly sheath) in a straight line to the tip. Pelvic-fin length is taken from base of first ray to tip of longest ray.

Table 1 contains proportional measurements of the new species as percentages of standard length. Measurements expressed as ratios related to standard length, body depth or head length in the text are rounded to the nearest 0.05.

Lateral-line scales were counted on the ocular side, from caudal-fin base to branching point of lateral line on head (including scales anterior to dorsal end of gill opening). Some authors have quoted lateral-line scale counts for *S. macleayanus* to include only those to the dorsal end of the gill opening (Ogilby, 1916: 127; Munro, 1957: 17; Marshall, 1964: 464). These counts are approximately equivalent to counts presented here minus 10. Conversely, counts provided by Ramsay (1881) for *S. macleayanus* and Ramsay (1882) for *S. fluviatilis* (a junior synonym of the latter), include pored scales on caudal fin and are about equivalent to our counts plus 10. Scale counts above and below lateral line are highest obtained on ocular side in oblique row between lateral line and outer edge of scaly sheath at the base of dorsal and anal fins, respectively.

We follow Ochiai (1963: Text-fig. 1a) for terminology of cephalic lateralis system and count of dorsal pterygiophores anterior to fourth neural spine (incorrectly stated as third spine, since he overlooked neural spine of tiny first vertebra). Counts of abdominal vertebrae include first very small vertebra, not counted by some authors.

Where different, values for paratypes are given in parentheses following those of holotype.

Use of Cyanine Blue 5R (Acid Blue 115), as demonstrated by Saruwatari et al. (1997), facilitated detection of pores, sensory papillae, and cteni of scales.

SYSTEMATICS

Synclidopus Chabanaud, 1943

TYPE SPECIES. *Solea macleayana* Ramsay, 1881.

DIAGNOSIS. As per Randall (2005), except: Dorsal rays 62-68; anal rays 48-53; lateral-line scales 87-113; vertebrae 35-38; dorsal branch of lateral-line on head sometimes with posterior and/or anterior sharply-angled projections on anterior part of body beneath dorsal fin; scales on blind side of head anterior to jaws replaced by cirri; well-developed free fleshy sheath covering anterior half of lower jaw and lower lip on blind side; stout papillae along anterior margin of snout and ventral margin of head, extending narrowly onto blind side of head; body depth 2.15-2.70 in SL; HL 4.25-5.50 in SL; eye diameter 6.90-9.75 in HL.

REMARKS

The diagnosis of *Synclidopus* provided by Randall (2005) was based on specimens of *S. macleayanus* measuring 72-149mm SL. *Synclidopus hogani* is only known from material of 48.0-61.6mm SL, so proportional measurements of additional material of *S. macleayanus* in this size range were obtained for the generic diagnosis and for direct comparison of the two species. This additional data produced significant expansion of some morphometric values for the genus, as might be expected with ontogenetic development. Small specimens of *S. macleayanus* usually lacked development of the sharply-angled posterior projection to the dorsal branch of lateral-line on the anterior part of the body, as noted in larger specimens by Randall. Also, some large specimens examined here had a short anterior horizontal projection instead of, or in addition to, a posterior one.

Synclidopus is closely related to the speciose *Aseraggodes* (see Randall, 2005), but is readily distinguished by the well-developed free fleshy sheath that covers the anterior half of the lower jaw including the lower lip (no free sheath in *Aseraggodes*), stout papillae along the anterior margin of the snout and ventral edge of the head (long slender cirri in *Aseraggodes*), and strikingly banded colouration (variously spotted, blotched

FIG. 1. Radiograph image of holotype of *Synclidopus hogani* sp. nov., QM I.38104, 61.6mm SL.

or uniform colouration in *Aseraggodes*). A combination of three branches of the lateral line on the ocular side of the head (the dorsal branch being long and vertical), small eyes, high number of lateral-line scales, scales on blind side of head anterior to jaws replaced by cirri, pelvic-fin rays 5 (3-4, rarely 5 in *Leptachirus*, 4-5 in *Pardachirus*); ocular-side pelvic fin broadly attached to the first anal ray (not attached in *Leptachirus* or *Pardachirus*, except in *P. poropterus*), absence of prominent pores at the base of the rays of the median fins (pores present in *Pardachirus*), 7 dorsal pterygiophores anterior to the fourth neural spine (7-16, only one with 7 or 8, in *Aseraggodes*, 7-11 in *Leptachirus*, 10-18 in *Pardachirus*), and banded colour pattern are also useful in separating it from *Aseraggodes*, *Leptachirus* and *Pardachirus* (Randall, 2005, 2007; Randall & Johnson, 2007; Randall & Desoutter-Meniger, 2007). Species of *Synclidopus* are found in shallow freshwater, estuarine, or inshore marine habitats, whereas species of *Aseraggodes* are found only in marine habitats, in various depths from shallows to over 100m. *Leptachirus* species are found in freshwater or upper estuarine conditions (Randall, 2007). Most *Pardachirus* species are marine, except the estuarine *P. rautheri* and estuarine/lower freshwater *P. poropterus* (Randall & Johnson, 2007).

Synclidopus hogani sp. nov.
(Fig. 1-4, 6; Tables 1-3)

MATERIAL. HOLOTYPE. QM I.38104, 61.6mm SL, female, Australia, Queensland, Daintree River, upstream from Daintree township, 16°14.69'S, 145°18.44'E, 0.4-0.8 m, electrofishing, A. Hogan, J. Johnson and M. Ekins, 28 November 2006. PARATYPES. AMS I.44260-001, 56.6mm; BPBM 40656, 56.0mm; QM I.38105, 2: 50.2–58.8mm, all with same data as holotype; QM I 36402, 53.0mm, Daintree River, upstream from Daintree township, 16°14.75'S, 145°18.4'E, maximum depth 50cm, electrofishing, W. Hagedoorn, 18 June 2002.

OTHER MATERIAL (NON-TYPE). QM I.38117, 48.0mm, same data as holotype, fixed in alcohol for possible future DNA analysis.

DIAGNOSIS. Dorsal-fin rays 64-68; anal-fin rays 48-52; lateral-line scales 87-97, median 94; abdominal vertebrae 10; total vertebrae 35-36; dorsal pterygiophores anterior to fourth neural spine 7; body depth 2.35-2.70 in SL; HL 4.25-4.85 in SL; eye diameter 6.90-8.25 in HL; stout papillae (not long slender cirri) on anterior edge of snout and ventral edge of head (visible from above on ocular side); scales on blind side of head replaced by cirri anterior to region just posterior to rear of jaws; straight lateral line midlaterally on both sides, forming three branches on ocular side of head: ventral preopercular branch, vertical dorsal branch nearly to base of dorsal fin, and short horizontal continuation of main lateral line; distinct free fleshy sheath on blind side, extending over front half of lower jaw, including lower lip and sometimes part of upper lip when mouth fully closed; ocular side with about 22-26 irregular, mostly discontinuous, transverse brown bands slightly wider than pale interspaces, and three longitudinal rows of 5-6 large diffuse dark brown spots.

DESCRIPTION. Dorsal-fin rays 65 (64-68); anal-fin rays 51 (48-52); dorsal- and anal-fin rays unbranched; caudal-fin rays 18, 14 branched, 3 double-branched at tips; pelvic rays 5, unbranched; lateral-line scales 94 (87-97),

including about 8 extending horizontally from upper end of gill opening to point of branching; lateral line on head with vertical branch of 16 (15-17) scales, ventral branch of 8 (6-8) scales over preoperele, and terminal horizontal branch of 6 (6-8) pored scales; lateral line continuing onto caudal fin nearly to posterior end of fin; scales above lateral line in oblique row to upper edge of scaly basal sheath of dorsal fin about 38; scales below lateral line about 44; abdominal vertebrae 10, caudal vertebrae 26 (25-26, one paratype with one and another with two fused caudal vertebrae bearing multiple neural and haemal spines, each counted as two separate vertebrae); total vertebrae 36 (35-36); first two dorsal proximal pterygiophores joined to thicker bone (the crisma) and counted as one pterygiophore (branched distally to support first two dorsal-fin rays); seven dorsal pterygiophores anterior to fourth neural spine (one anterior to second neural spine, four between second and third neural spines, and two between third and fourth neural spines); ventroanterior margin of urohyal forming an angle of about 85°, inner angle well rounded (Fig. 4).

Body depth 2.45 (2.35-2.70) in SL; body thin, width (thickness) 4.0 (4.15-4.50) in body depth; HL 4.85 (4.25-4.85) in SL; no caudal pedunele (base of posteriormost anal-fin ray slightly posterior to base of ventral caudal-fin ray); depth of caudal-fin base 1.55 (1.45-1.75) in HL; snout not overlapping and only projecting slightly anterior to lower lip when mouth closed; snout length 3.10 (3.05-3.25) in HL; preorbital length 3.55 (3.55-4.00) in HL; eye diameter 7.45 (6.90-8.25) in HL; least vertical interorbital width 10.60 (10.90-13.45) in HL; upper eye overlapping one-third (one-third to one-half) of lower eye; horizontal line projected anteriorly from dorsal end of gill opening passing one eye diameter below lower eye.

Posterior end of mouth on ocular side slightly ventral to lower margin of orbit and slightly posterior to anterior margin of orbit, jaw angling upward to point slightly anterior to centre of lower eye, then horizontal to ventral

TABLE 1. Proportional measurements as percentage of standard length and meristic values for type specimens of *Synclidopus hogani*.

	Holotype	Paratypes				
	QM I.38104	AMS I.44260	BPBM 40656	QM I.38105	QM I.38105	QM I.36402
Standard length (mm)	61.6	57.3	56.1	60.0	50.2	53.0
Body depth	40.7	40.3	37.0	38.8	42.8	40.2
Body width	10.2	9.0	8.2	9.4	9.6	6.6+
Head length	20.6	21.4	21.3	21.1	23.5	20.7
Snout length	6.7	6.7	7.0	6.5	7.2	6.8
Preorbital length	5.8	5.5	5.4	5.3	6.6	5.8
Eye diameter	2.8	2.7	2.7	2.6	3.0	3.1
Interorbital width	1.9	1.6	1.8	1.7	1.8	1.9
Upper-jaw length	5.7	5.5	5.9	5.3	7.0	7.2
Base of caudal fin	13.1	13.1	13.0	12.8	13.3	14.2
Predorsal length	7.6	8.0	8.0	7.7	8.2	7.7
Preanal length	21.1	23.9	22.3	23.6	26.1	24.7
Prepelvic length	16.7	18.2	17.9	17.3	21.7	17.0
First dorsal ray	3.7	3.4	3.2	3.2	3.8	3.6
Longest dorsal ray	11.2	11.5	10.4	11.2	12.0	12.3
First anal ray	6.5	6.4	5.4	6.0	6.8	6.6
Longest anal ray	11.2	9.9	10.0	11.2	12.0	11.5
Caudal-fin length	20.6	21.4	19.6	19.4	23.9	23.2
Pelvic-fin length	9.9	11.0	9.3	9.7	8.2	10.6
Dorsal rays	65	68	68	67	65	63
Anal rays	51	52	52	51	48	48
Caudal rays	18	18	18	18	18	18
Lateral line	94	95	97	96	93	87
Vertebrae	10+26	10+25	10+26	10+26	10+25	10+26

flap of upper lip (which does not overlap lower lip); cleft of mouth on blind side strongly curved; free fleshy sheath profusely covered in fleshy unbranched papillae extending from chin, over anterior half of lower lip, and part of upper lip on blind side when mouth fully closed; scales covering posterior end of ocular-side maxilla to level below centre of lower eye; length of blind-side upper jaw 3.65 (2.9-4.0) in HL; curved band of villiform teeth on blind side of both jaws, broader centrally, in at least twelve rows at widest part; ocular-side anterior nostril tubular, in slight depression anterior to horizontal from dorsal third of lower eye and ventral half of interorbital space, slightly tapering, approximately one-half eye diameter in height, located above upper lip at point about one-third distance between anterior margin of lower eye to snout tip; posterior nostril of ocular side a slit in labial groove before base of dorsal part of lower eye; tubular posterior nostril of blind side flat, strongly tapering, adherent to head for most of its length, twice size of blind-side anterior nostril, in shallow depression dorsoposterior to anterior nostril, internarial distance about 1.6 times cutaneous diameter of lower eye.

Scales ctenoid on both sides of body, most on body and postorbital part of head with 6-8 moderately long ctenii that project posterior to scale margins, longest ctenii about 4-6 times in length of scale; scales on ocular-side snout small and with fewer ctenii, anteriormost without ctenii, becoming short stout papillae near and at margin of snout and ventral margin of head; scales on blind side of head altering to long fleshy cirri before posterior end of jaws, cirri profusely covering region above and below jaws on blind side, becoming stouter and more papillae-like closer to anterior margin of head and on fleshy sheath covering anterior part of lower jaw; eyes separated by 2-3 rows of scales, with 2-3 rows of scales extending onto medial margins of eyes; series of about 34 slender cirri along opercular margin of gill opening on blind side, but no cirri on ocular side; small scales in 3-4 rows extending onto bases of dorsal- and anal-fin rays; caudal-fin base with about 14 oblique rows of progressively smaller scales extending out on fin to within about one-fourth distance to posterior margin.

Lateral line straight on both sides along middle of body, forming three branches on ocular side of head: long dorsal branch extending vertically close to base of dorsal fin, short ventral preopercular branch, and straight anterior branch projecting toward dorsal margin of upper eye; cephalodorsal sensory line submarginal on ocular side of snout, mostly evident as thin groove; lateral line extending onto caudal fin dorsal to ninth ray, nearly to posterior margin of fin; lateral line of blind side extending onto head as series of sensory papillae (obscured anteriorly by cirri), and not dividing; cephalodorsal sensory line on blind side also obscure because of cirri.

Dorsal fin originating anteriorly on snout, first ray not prolonged, dorsal-fin origin anterior to horizontal through ventral margin of upper eye; predorsal length 2.70 (2.65-2.90) in HL; first dorsal-fin ray 5.50 (5.75-6.60) in HL; longest dorsal-fin ray 1.85 (1.70-2.05) in HL; anal-fin origin below base of about fourteenth dorsal-fin ray, preanal length 4.75 (3.85-4.50) in SL; first anal-fin ray 3.20 (3.15-3.95) in HL; longest anal-fin ray 1.85 (1.80-2.15) in HL; dorsal- and anal-fin rays on both sides with thin membranous ridge extending from bases to at least three-fourths distance to ray tips, ridges more well developed on blind side, first nine dorsal-fin rays on blind side with fleshy cirri on medial edges of ridges; membranous fold on blind side of each fin ray forming a pocket-like space posteriorly, membranous tissue with inner transverse fleshy ridges that are often associated with perforations through the membrane; tips of dorsal- and anal-fin rays free of membrane except for five anteriormost dorsal-fin rays; anus ventroanterior to first anal-fin ray, rimmed with fleshy papillae; genital papilla on blind side at posterior margin of anus, situated at immediate base of first anal-fin ray, not connected to anal or pelvic fins by membrane; caudal fin rounded, but slightly pointed medially, 4.85 (4.20-5.15) in SL, not broadly connected by membrane to dorsal and anal fins; ocular-side pelvic fin on ventral edge of body, the origin at gill opening, the last membrane broadly attached to first anal-fin ray; blind-side pelvic fin about one fin-ray width posterior to origin of ocular-side fin, ending short distance before anus; third and fourth pelvic-fin rays longest, fin length 2.10 (1.95-2.90) in HL.

Colour of ocular side of female holotype (Figs 2A, 3, 4A-B) pale creamy brown with numerous (about 25, but difficult to count accurately), irregular, diffuse, transverse darker brown bands about equal to eye diameter in width, many branching, most not continuous across body depth, separated by pale interspaces of lesser width; three longitudinal rows of five or six large, poorly-defined, dark brown spots, most vertically elongate, one

row below base of dorsal fin, one above base of anal fin, and one along lateral line; brown streaks in dorsal- and anal-fin rays, most along every other ray and adjacent membranes; caudal fin pale with small dark spots or streaks, and three large diffuse brown spots across base; colour of blind side pale yellowish cream, becoming pale orange over abdomen. Paratypes with about 22-26 transverse bands, the latter mostly lighter in colour than in the holotype. Two paratypes have the longitudinal rows of large dark brown spots on the body more distinct than in the other type specimens.

ETYMOLOGY. Named *hogani* for Alf Hogan, Fisheries Biologist, Queensland Department of Primary Industries and Fisheries Research Station, at Walkamin, Queensland. Alf has made a major contribution to the understanding of freshwater fishes of north Queensland over the last 30 years. He has added many rare and poorly-known fishes to museum collections and his electrofishing skills were invaluable in the capture of type material of this species.

DISTRIBUTION

Known only from the type locality (Fig. 6) in tidal lower freshwater reaches of the Daintree River, upstream from the township of Daintree (approximately 16°14.7'S, 145°18.4'E).

COMPARISON

The new species is distinguished from its only known congener, *S. macleayanus* (Ramsay, 1881), primarily by its lower lateral-line scale count (87-97, median 94 versus 94-113, median 101, Table 2), colouration, and much smaller maximum size attained. *Synclidopus hogani* generally has a pattern of dark bands on a pale background, however the bands are fewer (about 22-26, but difficult to count accurately), highly irregular, diffuse, mostly discontinuous, variable in width, not strongly contrasting with the paler interspaces, and pale tan to dark chocolate brown with light creamy brown interspaces in life. *Synclidopus macleayanus*, in contrast, has more numerous bands (26-40, mode 32, smaller specimens with bands more numerous than in adults) that are regular, well-defined, some forked, but most unbroken, starkly contrasting with pale interspaces, and are dark charcoal grey-brown with whitish to pale lavender-grey interspaces in life (Fig. 5). In addition, *S. hogani* has three longitudinal rows of large poorly-defined dark brown spots that are missing in *S. macleayanus*. Morphology of the two species is very similar, however, on average *S. hogani* has a slightly longer head and larger eyes (Table 3). The two species are allopatric, with *S. macleayanus* known from the east coast of Australia between the Burnett River mouth, Qld (24°40'S) and Sydney Harbour, NSW (33°50'S), including Lord Howe Island. Hoese et al. (2006: 1843) reported the range of this species as Gulf of Carpentaria to Sydney, but the single Gulf of Carpentaria record was based on a mislabeled specimen from Moreton Bay. The Daintree River is approximately 1200km north of the northern extremity of the known range of *S. macleayanus*. The maximum reported size of *S. macleayanus* is 280mm TL (Ogilby, 1916), whereas the largest known specimen of *S. hogani* is the 74.3mm TL female holotype. The latter has a relatively large ovary (12mm in length), so is estimated to be close to maturity.

DISCUSSION

All type material of *S. hogani* was collected on a broad shallow bank that occupies much of the southern side of the Daintree River, several kilometers upstream from the Daintree township (Fig. 6). They were taken on coarse sand and gravel substrate, which included numerous fallen

TABLE 2. Frequency of lateral-line scale numbers in material examined of *Synclidopus* species.

	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108
hogani	1	-	-	-	-	-	2	1	1	1	1	-	-	-	-	-	-	-	-	-	-	-
macleayanus	-	-	-	-	-	-	-	1	2	2	-	2	3	5	5	3	3	2	2	1	1	1

TABLE 3. Comparison of selected relative body measurements in specimens of *Synclidopus hogani* and *S. macleayanus* of a similar size range.

Ratio	*S. hogani* (n = 6)	*S. macleayanus* (n = 5)
SL (mm)	50.2-61.6	54.5-76.0
Head length in SL	4.25-4.85 (mean 4.70)	4.70-5.30 (mean 5.00)
Body depth in SL	2.35-2.70 (mean 2.50)	2.25-2.60 (mean 2.40)
Eye diameter in HL	6.90-8.25 (mean 7.75)	7.65-9.75 (mean 8.45)

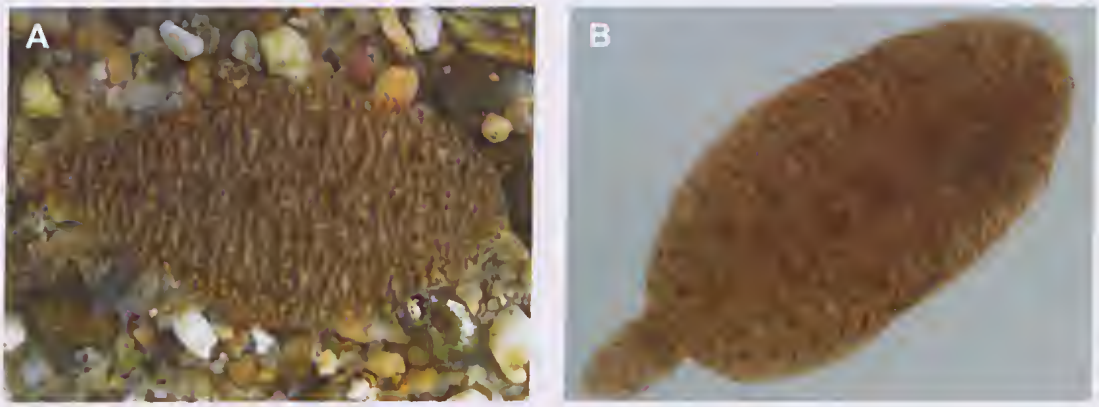

FIG. 2. Type specimens of *Synclidopus hogani* sp. nov. in life. A, Holotype, QM I.38104, 61.6mm SL; B, Paratype, QM I.38105, 50.2mm SL.

FIG. 3. Holotype of *Synclidopus hogani* sp. nov., QM I.38104, 61.6mm SL, preserved.

leaves and the open shells of freshwater bivalve molluscs. The riverine environment at the type locality is flowing, clear and fresh (being about five or six kilometres upstream from the brackish zone), but is clearly subject to tidal influence, with about a 75cm rise and fall. Physical data taken with the holotype on 28 November 2006 included: conductivity 59.6-60.6 µS/cm (approximately 30 ppm), pH 6.8, temperature 29°C, dissolved oxygen 6.5 ppm, and turbidity 0.8 NTU. Salinity at the type locality was similarly low when paratype QM I.36402 was collected in June, 2002 (conductivity was 75 µS/cm, or 37.5 ppm). Other fishes recorded within about 300m of the type locality on 28 November 2006 included *Anguilla reinhardtii, Megalops cyprinoides, Nematalosa erebi, Chanos chanos, Neosilurus ater, Arrhamphus sclerolepis, Melanotaenia splendida splendida, Pseudomugil signifer, Notesthes robusta, Lates calcarifer, Ambassis agassizii, Ambassis miops, Hephaestus fuliginosus, Mesopristes argenteus, Glossamia aprion, Caranx sexfasciatus, Leiognathus equulus, Lutjanus argentimaculatus, Gerres filamentosus, Acanthopagrus australis, Toxotes chatareus, Mugil cephalus, Awaous acritosus, Glossogobius* sp. 1 (of Allen et al., 2002: 269), *Redigobius bikolanus, Giuris margaritacea* and

FIG. 4. Holotype of *Synclidopus hogani* sp. nov., QM I.38104, 61.6mm SL. A, Dorsal view of head, showing robust papillae; B, Ventral view of head, showing numerous papillae and fleshy sheath covering anterior part of lower jaw.

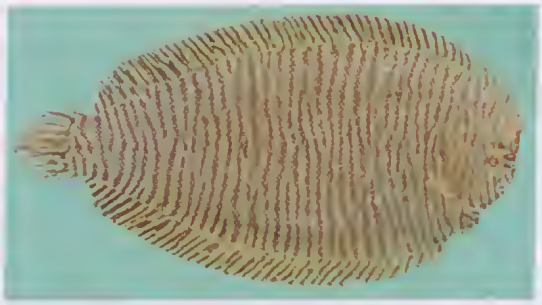

FIG. 5. *Synclidopus macleayanus*, BPBM 39454, 149mm SL, off Sydney, NSW.

Hypseleotris compressa. Estuarine crocodiles, *Crocodylus porosus*, are also well known from the area.

The gut contents of one paratype of *S. hogani* included fragments of insect larvae and numerous sand grains.

Some soles of the genus *Aseraggodes*, and more particularly *Pardachirus*, are known to repel predators and possibly stun potential prey items using a powerful crinotoxin exuded from the skin or specialised pores at the bases of rays of the median fins (e.g. Clark & Chao, 1973; Randall, 2002; Randall & Meléndez, 1987). The toxin is reported as having a milky white appearance, bitter taste, and lethal effect on small fishes if they are confined with it in a small body of water. Experiments to determine whether *S. hogani* had this capacity were conducted in the field shortly after collection of the type specimens. All were landed alive and well, and to minimise stress they were retained in a large, shaded and well-aerated container before the tests. Attempts were made to induce production of the toxin by gently and repeatedly massaging the body and median fins of two specimens, however, no milky exudate was visibly evident, and clear mucus from the body and fins had no bitter taste. These fish were then immediately introduced to a vessel containing about one litre of water, eight small empire gudgeons (*Hypseleotris compressa*), and four small Pacific blue-eyes (*Pseudomugil signifer*). After one hour all fish were healthy and showing no signs of stress. In case electric shock from the electrofishing gear had caused the *S. hogani* to discharge and exhaust their reserves of toxin, we repeated the process after two days, but the same results were obtained. We therefore conclude that *S. hogani* produces no significant amounts of toxin externally through the skin or pores, or at least none of a similar nature to that reported for *Pardachirus* or some *Aseraggodes* species.

FIG. 6. Daintree River, looking downstream to type locality of *Synclidopus hogani*.

Synclidopus hogani has been collected in mid June, early in the dry season, in August, and at the end of November, which usually immediately precedes the wet season. Attempts to survey the type locality in April and other wet season periods were unsuccessful due to high river levels and strong flows. Having been found in the same reach of the river at widely separated times of the year, the species obviously occupies the tidal lower freshwater reaches for much if not all of the year, and thus seems to prefer freshwater rather than brackish habitats. The estuary and beaches adjacent to the Daintree River mouth were also targeted for flatfishes by dragging heavily weighted seines with large cod ends. While these were effective in producing numerous specimens of other small flatfishes (*Paraplagusia bilineata*, *Pseudorhombus arsius* and *P. elevatus*) and flatheads (*Platycephalus endrachtensis* and *P. fuscus*), no additional specimens of *S. hogani* or other soleids were taken. Other surveys of the Daintree River estuary (Russell et al., 1998) and other estuarine systems of northeastern Queensland (e.g. Blaber, 1980; Coles et al., 1993; Russell & Hales, 1993; Russell et al., 1996; Russell et al., 2000) using beam trawl and small-meshed seines have captured various soleids, including *Brachirus orientalis*, *B. muelleri*, *Paradicula setifer*, *Pardachirus rantheri* and *Soleichthys heterorhinos*, but have been similarly unsuccessful in collecting *S. hogani*. Surveys and regular long-term monitoring programs in freshwater reaches of all other rivers in the wet tropics region of northeastern Queensland using electrofishing gear have also failed to produce any specimens of this species.

OTHER MATERIAL.*Synclidopus macleayanus*. 33 specimens, 54-168mm SL. New South Wales: BPBM 39454, 149mm, off Sydney. Queensland: QM I.621, 2: 65-76mm, Brisbane River; QM I.1664, 135mm, Moreton Bay; QM I.1665, 121mm, Moreton Bay; QM I.1666, 100mm, Moreton Bay; QM I.2504, 92mm, Cowan Cowan, Moreton Bay; QM I.3344 121mm, S Qld coast; QM I.3367 143mm, S Qld coast; QM I.5050, 93mm, Clontarf, Moreton Bay; QM I.9484, 106mm, Gneering Shoals, off Mooloolaba; QM I.9485, 58mm, Brisbane River; QM I.9788, 112mm, E of Burleigh Heads; QM I.9789, 100mm, E of Burleigh Heads; QM I.10596, 3: 100-118mm, Moreton Bay; QM I.12360, 113mm, Moreton Bay; QM I.12361, 105mm, Moreton Bay; QM I.12987, 2: 107-108m, Moreton Bay, off Redcliffe; QM I.13089, 99mm, NE of Cape Moreton lighthouse; QM I.14514, 2: 90-93mm, Moreton Bay, off Redcliffe; QM I.19382, 101mm, Moreton Bay, off Brisbane River mouth; QM I.23877, 135.5mm, Burnett River mouth; QM I.25336, 54mm, Brisbane River mouth; QM I.26373, 2: 88-94.5mm, Deception Bay, Moreton Bay; QM I.30669, 105mm, Moreton Bay, N end of Western Banks; QM I.30687, 69.5m, Moreton Bay, shell banks S of Bribie Island; QM I.34194, 108mm, E of Southport; QM I.38114, 168mm, 13 miles E of Kolan River mouth, 24°40'S 152°25'E.

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A REVIEW OF THE *POLYRHACHIS* ANTS OF SULAWESI WITH KEYS AND DESCRIPTIONS OF NEW SPECIES (HYMENOPTERA: FORMICIDAE: FORMICINAE)

RUDOLF J. KOHOUT

Kohout, R.J. 2008 04 30: A review of the *Polyrhachis* ants of Sulawesi with keys and descriptions of new species (Hymenoptera: Formicidae: Formicinae). *Memoirs of the Queensland Museum* 52(2): 255–317. Brisbane, ISSN 0079-8835.

Eighty-four species of the ant genus *Polyrhachis* are listed from Sulawesi, including twenty-five described as new: *P. aberrans, P. arborea, P. bosi, P. brachyspina, P. brendelli, P. browni, P. chaita, P. cognata, P. deceptor, P. festina, P. gobini, P. hilaris, P. hispida, P. imitator, P. incognita, P. kaznoi, P. manni, P. masaokai, P. mellita, P. neglecta, P. ogatai, P. salebrosa, P. storki, P. stricta* and *P. sulawesiensis*. *Polyrhachis formicata* Emery is re-described and the worker of *P. trispinosa* Fr. Smith, a species known only from the queen caste, is described. Five former subspecies, *P. aculeata cybele* Wheeler, *P. aculeata gibbosa* Forel, *P. fruhstorferi varicolor* Viehmeyer , *P. rastellata pagana* Santschi and *P. zopyra edentula* Emery, are raised to species. *Polyrhachis spinosa* Mayr synonymised earlier with *P. hubastes* Fr. Smith is reinstated as a valid species. *Polyrhachis tricuspis* André is considered a senior synonym of *P. ternatae* Karawajew. *Polyrhachis arcuata* (Le Guillou) and *P. muelleri* Forel are listed from Sulawesi for the first time. *Polyrhachis javanica* Mayr, previously recorded from Sulawesi, is considered not to occur there. Four new species-groups are proposed: the *P. vestita*-group within the subgenus *Myrma* Billberg, the *P. flavicornis*-group within the subgenus *Myrmatopa* Forel and the *P. aequalis*- and *P. thrinax*-groups within the subgenus *Myrmothrinax* Forel. All new and some previously described species are illustrated. ❐ *Polyrhachis, Sulawesi, Project Wallace, new species, synonymy.*

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The Indonesian island of Sulawesi, formerly known as Celebes, occupies a central position in the Malay Archipelago. It is situated east of Borneo and flanked by the Makassar Strait and the Celebes, Molucca and Banda Seas. Sulawesi has traditionally been subdivided into four administrative provinces, Sulawesi Utara (North), Sulawesi Tengah (Central), Sulawesi Tenggara (South-East) and Sulawesi Selatan (South) with two more provinces, Sulawesi Barat (West) and Gorontalo, created in recent years.

In biogeographical terms, Sulawesi has always been difficult to classify. Several biogeographical lines have been drawn betweeen the Indo-Malayan and Australasian regions based on the distributions of different taxonomic groups, but only Wallace's and Weber's lines persisted until the 20th century (Humphries, 1990). The geographical area between these two lines was named Wallacea (Dickerson, 1928) and has been used to indicate the unresolved biogeographical position of this region which, besides Sulawesi, includes the Moluccas, Lesser Sundas and numerous smaller eastern Indonesian islands (Humphries, 1990).

Although the Sulawesian fauna and flora are not considered as rich as those of the neighbouring larger islands, they contain a vast number of endemic elements. Sulawesi is regarded as a biodiversity hotspot (see www.biodiversityhotspots.org) and is renown for its biogeographical uniqueness and complexity, with the most distinctive elements found in its tropical rainforests (Marshall & Collins, 1990). However, in recent years, many farmers from Java and Bali have settled in Sulawesi resulting in increased rates of deforestation, particularly in the South and South-East provinces. It has been estimated that less than half of the island remains forested and only a fraction of it can be regarded as undisturbed, primary forest. More recently however, moves have been made to conserve Sulawesi's forests both by rehabiliting degraded forests and by preservating areas of primary forest (Kucera, 1990). To reduce the increasing pressure upon Sulawesian primary forests, a range of reserve areas have been

designated over the past few decades including Lore Lindu, Morowali and Dumoga-Bone National Parks.

For the most part this paper deals with material collected in Dumoga-Bone National Park during Project Wallace, the 1985 joint expedition of the Royal Entomological Society of London and the Indonesian Institute of Sciences (LIPI) to North Sulawesi, led by Dr N.E. Stork. Also included are sizable collections made before and after the expedition by Dr M.J.D. Brendell of the Natural History Museum, London, UK and Dr Ing. C. van Achterberg of the Nationaal Natuurhistorisch Museum, Leiden, The Netherlands. In addition, material collected by Dr Bruno Gobin of the Katholieke Universiteit, Leuven, Belgium, provided several species not collected by the expedition, including the type series of a new species. More recent material, including six new species, was collected from South and South East Sulawesi by Drs K. Ogata and K. Masaoka during the 1999 field survey jointly conducted by the Institute of Tropical Agriculture at the Kyushu University, Japan, the Indonesian Institute of Sciences (LIPI) and Hasanuddin University, Ujung Pandang. Additional material was provided by Prof. Dr Seiki Yamane, Faculty of Science, Kagoshima University, Japan, Prof. Datin Dr Maryati Mohamed, Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Malaysia, Dr Joehen Ketterl, Staatliches Museum für Naturkunde, Stuttgart, Germany, and Dr Jerome Constant, Royal Belgian Institute of Natural Sciences, Brussels, Belgium. Most recently, a substantial collection of Sulawesian *Polyrhachis*, collected by canopy fogging in Lore Lindu National Park and surrounding cacao plantations, was received from Merijn M. Bos of Götingen University, Germany. This material was received near the completion of the current paper and could not be fully incorporated. However, three new species have been described from this material and numerous records of other species included. Considering that Project Wallace centred on a relatively small area of Sulawesi, and that only limited collections are available from other parts of the island, I believe that the list of species presented here does not reflect the full richness of the Sulawesian *Polyrhachis* fauna.

HISTORICAL REVIEW

In 1860 and 1861 Frederick Smith described the first twenty-five species of *Polyrhachis* from Sulawesi, from specimens collected in 1856 and 1857 at Makassar (= Ujung Pandang) and in 1859 at Menado (= Manado) by Alfred Russel Wallace. In following years, a further twenty-one new species and subspecific forms were added by various authors, including Emery, Forel and Viehmeyer, bringing the number of *Polyrhachis* species described from the island to forty-six. This number includes eight species (and subspecies) described from copal and eleven which are now considered junior synonyms of senior taxa described from Sulawesi or from elsewhere in South East Asia. In addition, more than 20 extralimital species have been reported from Sulawesi by various authors, however, at least half of these records remain doubtful, while some are obviously erroneous.

MATERIAL AND METHODS

The present paper lists eighty-four species of *Polyrhachis* from Sulawesi, including twenty-five species described as new, and four species previously known only from other parts of Indonesia. Also included in the total are a number of species that have not recently been collected from the island, but have Sulawesi as their original provenance, or that have been confidently recorded there by reliable sources. Their absence from recent collections is in spite of a wide range of collecting methods having been employed, including canopy fogging (Martin Brendell, Nigel Stork and Merijn Bos), Malaise traps (C. van Achterberg) and general hand collecting (Bruno Gobin, Kazuo Ogata and K. Masaoka). Material examined is listed under the four traditionally recognised provinces of the island. Material from the two relatively recently created provinces, Sulawesi Barat and Gorontalo, is included within Sulawesi Selatan and Sulawesi Utara respectively.

Publication dates and the spelling of species and authors' names follow those of Bolton (1995), except for the name of Wladimir Karawajew, where the original spelling used by that author himself (e.g. 1927 etc) has been followed. Where a holotype specimen is mentioned as 'unique', this infers that it was the only specimen available for description and no syntype or paratype specimens are known to exist.

Most images were taken with a digital camera attached to a stereomicroscope and processed using Auto-Montage (Syncroscopy, Division of Synoptics Ltd, USA) and Adobe CS2 (Adobe Systems Inc, USA) software. Photographs of specimens collected by Merijn Bos were processed using Helicon Focus (Mac OSX version) and

Adobe Photoshop software. Unless otherwise indicated, all digital images of the new species depict the primary types. Those of previously described species represent the types or type-compared specimens.

The measurements (in mm) and indices follow those of Kohout (1990): TL = Total length (the necessarily composite measurement of the entire ant); HL = Head length (the maximum measurable length of the head in perfect full face view, measured from the anterior-most point of the clypeal border or teeth, to the posterior-most point of the occipital margin); HW = Head width (width of the head in perfect full face view, measured immediately in front of the eyes); CI = Cephalic index (HW x 100/ HL); SL = Scape length (length of the antennal scape, excluding the condyle); SI = Scape index (SL x 100/HW); PW = Pronotal width (width of the pronotal dorsum measured at the bases of the pronotal spines, or across the humeri in species without spines); MTL = Metathoracic tibial length (maximum measurable length of the tibia of the hind leg). All measurements were taken using a Zeiss (Oberkochen) SR stereomicroscope with an eyepiece graticule calibrated against a stage micrometer.

Abbreviations and glossary of common and Indonesian terms: Barat = West; bukit = hill; fog. = fogging; for. = forest; FR = Forest Reserve; Gn. = Gunung = Mountain; I. = Island; Is = Islands; Mt = Mount; Mtn = Mountain; Mts = Mountains; NP = National Park; nat. for. = natural forest; agrof. = plantation; R. = River; rf. = rainforest; Selatan = South; Tengah = Central; Tenggara = South-East; Timur = East; Utara = North; w = worker/s.

Institutions and depositories (with the names of cooperating curators) are: AMNH – American Museum of Natural History, New York, NY, USA (Dr J.M. Carpenter); ANIC – Australian National Insect Collection, Canberra, Australia (Drs S.O. Shattuck, R.W. Taylor); BMNH – The Natural History Museum, London, UK (B. Bolton); BPBM – Bernice P. Bishop Museum, Honolulu, HI, USA (K.T. Arakaki); CASC – California Academy of Sciences, San Francisco, CA, USA (Dr B.L. Fisher); DEI – Deutsches Entomologisches Institut, Müncheberg, Germany (Dr A. Taeger); GUGG – Göttingen University, Göttingen, Germany (M.M. Bos); HNHM – Hungarian Natural History Museum, Budapest, Hungary (Dr J. Papp); IRSN – Institut Royal des Sciences Naturelles de Belgique, Brussels, Belgium (Drs P. Grootaert, P. Dessart, J. Constant); IZAS – Institute of Zoology, Ukrainian Academy of Sciences, Kiev, Ukraine (Dr A.G. Radchenko); KUKJ – Kagoshima University, Kagoshima, Japan (Prof. Dr Seiki Yamane); KULB – Katholieke Universiteit, Leuven, Belgium (Prof. Dr J. Billen); MCSN – Museo Civico di Storia Naturale 'Giacomo Doria', Genoa, Italy (Drs R. Poggi, V. Raineri); MCZC – Museum of Comparative Zoology, Harvard University, Cambridge, MA, USA (Dr S.P. Cover); MHNG – Muséum d'Histoire Naturelle, Geneva, Switzerland (Drs C. Besuchet, I. Löbl, B. Mertz); MNHA – Museum of Nature and Human Activities, Hyogo, Japan (Dr Yoshiaki Hashimoto); MNHN – Muséum National d'Histoire Naturelle, Paris, France (Dr J. Casevitz-Weulersse); MNHU – Museum für Naturkunde, Humboldt-Universität, Berlin, Germany (Dr F. Koch, Ms Kleine-Möllhoff); NHMB – Naturhistoriseches Museum, Basel, Switzerland (Drs M. Brancucci, D.H. Burckhardt); NHMW – Naturhistoriseches Museum, Vienna, Austria (Drs M. Fischer, S. Schödl, H. Zettel); NMNH – National Museum of Natural History, Smithsonian Institution, Washington DC, USA. (Drs T. R. Schultz, D.R. Smith); NRMS – Naturhistoriska Riksmuseet, Stockholm, Sweden (Drs K-J. Hedquist, F. Ronquist, B. Viklund); OXUM – Hope Entomological Collections, University Museum, Oxford, UK (Drs C. O'Toole, D.J. Mann); PUPI – Punjabi University, Patiala, India (Dr Himender Bharti); QM – Queensland Museum, Brisbane, Australia (Drs C.J. Burwell, G.B. Monteith); RMNH – Nationaal Natuurhistorisch Museum, Leiden, The Netherlands (Dr Ing. C.van Achterberg); FIS – Forschungsinstitut Senckenberg, Frankfurt am Main, Germany (Drs J.-P. Kopelke, W.H.O. Dorow); SMNS – Staatliches Museum für Naturkunde, Stuttgart, Germany (Dr J. Ketterl); SNSD – Staatliche Naturhistorische Sammlungen, Museum für Tierkunde, Dresden, Germany (Drs R. Emmrich, U. Kallweit); UCDC – University of California, Davis, CA, USA (Dr P. Ward); UDSB – Universita Degli Studi di Bologna, Italy (Prof. Dr Maria M. Principi); ITBC – Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia (Prof. Datin Dr Maryati Mohamed).

SYSTEMATICS

NOMENCLATURAL CHANGES TO EXTRALIMITAL TAXA

During the progress of this study I have examined numerous types and other available specimens of several taxa, which directly or indirectly relate to the Sulawesian fauna of the genus. As a result, I propose a number of nomenclatural changes that are discussed throughout the text under their appropriate subgenera and species-groups. However, four that concern taxa that are distributed outside the main geographic scope of this paper are treated below.

Polyrhachis edentula Emery, 1900 stat. nov.

Polyrhachis zopyrus var. *edentula* Emery, 1900: 712; Forel, 1911 (description of queen and male). Syntype workers. Original localities: INDONESIA, SUMATRA, D. Tolong, Balighe, Pea Ragia, Si Rambé, Pangherang Pisang (E. Modigliani), MCSN (examined).

I have examined and directly compared the holotype of *Polyrhachis zopyra* (OXUM) with the syntypes of *P. zopyra edentula* and consider they represent separate species. They differ in several characters, including the outline of clypeus that, in lateral view, is weakly, but evenly convex with a flat basal margin in *P. edentula*, while it is straight and rounds into a weakly impressed basal margin in *P. zopyra*. The pronotal and petiolar teeth are distinctly more acute in *zopyra*, while in *P. edentula* they are shorter with the dorsal petiolar teeth obtuse and situated very close together. The pubescence in *P. zopyra* is very closely appressed, smooth and rather tidy, with only a few erect hairs arising from the gaster and the dorsum of head. The pubescence in *P. edentula* is more abundant and somewhat longer, with numerous erect hairs arising from all body surfaces, including the mesosoma and petiole.

Polyrhachis gibbosa Forel, 1908 stat. nov.

Polyrhachis aculeata var. *gibbosa* Forel, 1908: 9; Forel, 1913: 139 (description of queen). Syntype workers. Type locality: SRI LANKA, Puwakpitiya (E. Bugnion), MHNG (examined).

In order to establish the status of *Polyrhachis aculeata cybele* Wheeler (see below), I examined and directly compared the types of *P. aculeata* Mayr, *P. aculeata cybele*, *P. aculeata gibbosa* and a specimen of *P. hemiopticoides* Mukerjee identified by the original author (see Mukerjee, 1934: 11). All are similar, but I am confident in assigning specific rank to both the subspecies. The characters separating these four species include the degree to which the posterior blinkers of the eyes are developed, general pilosity and the shape and length of the pronotal and petiolar spines. In *P. aculeata* and *P. hemiopticoides* the eyes are strongly truncate and the pronotal and petiolar spines rather long and slender. *Polyrhachis aculeata* has all the body surfaces covered with numerous, relatively long, erect or semierect hairs and the legs and base of the gaster reddish-brown. In *P. hemiopticoides* hairs are present only on the head and over the gastral apex, and the gaster and tarsi are black with only the femora and tibiae reddish-brown. *Polyrhachis gibbosa* differs from both species and also from *P. cybele* by its distinctly less truncate eyes, stubby body, shorter and thicker petiolar spines and the presence of a distinct pile of short, silvery or whitish, appressed pubescence that is abundant over most of the body surfaces, except the vertex, midline of the mesosoma and gastral dorsum. *Polyrhachis gibbosa* is apparently limited to Sri Lanka, while *P. aculeata* and *P. hemiopticoides* are known from India, with the latter also reported from Laos. *Polyrhachis cybele*, which occurs on Borneo, Sumatra and Sulawesi is discussed in detail under the subgenus *Myrma* below.

Polyrhachis pagana Santschi, 1928 stat. nov.

Polyrhachis (*Cyrtomyrma*) *rastellata* var. *pagana* Santschi, 1928: 134, fig. 2c. Holotype worker. Type locality: INDIA, Kanara (Bell), NHMB (examined).

When describing *P. rastellata pagana*, Santschi compared his new variety to *P. euryala* Fr. Smith and *P. rastellata* (Latreille). He noted that it differed from *P. euryala* by having the dorsal petiolar spines longer and finer than the lateral pair, and from *P. rastellata* by its black appendages. I have examined a syntype of *P. euryala* and the holotype of *P. rastellata pagana*, together with numerous specimens of *P. rastellata*. Moreover, during a recent visit to India (PUPI), I examined the *Polyrhachis* material collected by Mukerjee (1934). Examination of all the available specimens has shown all three taxa to represent separate species. Besides the characters listed above, *P. euryala* differs from both other species by its distinctly slender mesosoma with the greatest width of the pronotal dorsum at its mid-length. In contrast, both *Polyrhachis rastellata* and P. *pagana* feature a more robust pronotal dorsum which is widest across or just behind the shoulders. The two latter species differ mainly by the colour of

their legs that are mostly light to medium-red or orange in *P. rastellata* and black in *P. pagana*. In addition, the mesosomal profile in *P. rastellata* is distinctly uneven, with a rather flat or shallowly impressed summit at the promesonotal suture and a weak depression indicating the relative position of the indistinct metanotal groove. In contrast, the mesosoma in *P. pagana* is almost evenly rounded (more like that in *P. euryala*), with only a slight change in the angle of the profile at the steeply descending propodeal declivity.

Polyrhachis tricuspis André, 1887

Polyrhachis tricuspis André, 1887: 284. Holotype queen (alate). Type locality: INDONESIA, Ambon I., IRSN, (examined).

Polyrhachis (Myrmothrinax) tricuspis André. Emery, 1925: 184.

Polyrhachis (Myrmothrinax) ternatae Karawajew, 1933: 105, fig. 7. Syntype workers. Type locality: INDONESIA, Ternate I. (F. Weyer), (W. Karawajew #5281), IZAS, QM (examined). **New synonymy.**

I have examined the unique holotype queen of *P. tricuspis* and compared it directly with a single available queen of *P. ternatae* from Seram I. The latter is a part of a series of specimens collected by W.M. Mann (Ceram, Piroe, 1937 NGS SI Exp.), with accompanied workers that have been compared with the syntype of *P. ternatae* and considered conspecific. In the original description, Karawajew compared *P. ternatae* with *P. fraueufeldi* Mayr from Java, however, it is more similar to *P. aequalis* Forel from the Philippines. Both species have short, but distinct humeral teeth, almost identical sculpturation of the mesosomal dorsum, subequal petiolar spines and a reddish-brown body and appendages. They mainly differ in the form of the median portion of the anterior clypeal margin that, in *P. ternatae*, has a widely open, 'V' shaped emargination, while it is simply truncate in *P. aequalis*.

Polyrhachis varicolor Viehmeyer, 1916 stat. nov.

Polyrhachis (Campomyrma) fruhstorferi ssp. *varicolor* Viehmeyer, 1916: 163. Syntype workers, queen. Type locality: SINGAPORE (H. Overbeek), MNHU (examined).

Polyrhachis (Myrmatopa) fruhstorferi ssp. *varicolor* Viehmeyer. Emery, 1925: 180.

I have examined two syntype workers of *P. fruhstorferi* Emery (MCSN) and three workers and a queen of the syntype series of *P. fruhstorferi varicolor* Viehmeyer (MNHU). Comparison of the types with recently collected specimens of *P. fruhstorferi* (see below) and *P. fruhstorferi varicolor* (THAILAND, Songkhla Prov., Ton Nga Chang Wildlife Sanctuary, Surachai Tongierm and CAMBODIA, Siem Reap, Banteay Srey, Kbal Spean, G.D. Alpert), clearly shows they are distinct species. The sculpturation in both species consists of reticulate-punctation, however, it is distictly finer in *P. varicolor*. The petiolar spines in *P. varicolor* are longer and more slender, while in *P. fruhstorferi* they are rather stubby. The colour of the body in *P. fruhstorferi* is mostly black, with only the legs and gaster very dark reddish-brown. In contrast, the body of *P. varicolor*, including the antennae and legs, is distinctly orange or light reddish-brown with the tarsi, gaster and apices of the petiolar spines darker reddish-brown and the frontal carinae and lateral margins of mesosoma narrowly lined with dark brown.

KEY TO SUBGENERA AND SPECIES-GROUPS OF *POLYRHACHIS* OF SULAWESI (based on workers)

1. Mesosomal dorsum distinctly laterally marginate along its entire length 2

   Mesosomal dorsum only partly marginate or totally immarginate 13

2. Pronotal humeri produced into more-or-less anteriorly directed spines (eg. Fig. 2A) 3

   Pronotal humeri rounded, angular or produced into broad-based short teeth (Figs 1C, E) 10

3. Propodeum usually with upturned teeth (Fig. 4B); petiole scale-like with dorsum armed or unarmed (*Myrma*, in part) 4

   Propodeum with posteriorly or upwardly directed spines (Fig. 11H); petiole columnar, armed with spines or teeth of various configurations 7

4. Dorsum of petiole with four spines or teeth (Fig. 2C) 5.

   Dorsum of petiole without spines, entire or at most obtusely jagged (Fig. 5G) 6

5. Mesosoma in profile evenly convex, without distinct border between dorsum and propodeal declivity; head with distinct postocular carinae ..... *Myrma continua*-group (only *P. continua* Emery)

   Mesosoma in profile with distinct border dividing dorsum from declivity; head without postocular carinae ..... *Myrma reluceus*-group

6. Large species (HL >2.30); whole body with numerous long or medium length erect hairs (Fig. 5B) ..... *Myrma vestita*-group

   Small species (HL <1.80); body with only a few short erect hairs on front of head and around gastral apex (Fig. 1H) ..... *Myrma inermis*-group

7. Dorsum of petiole armed with 3 mostly dorsoposteriorly directed spines of various lengths (Fig. 12A) (*Myrmothrinax*, in part) 8

   Dorsum of petiole armed with 2 mostly horizontal spines that usually conform to shape of gaster (Fig. 9A) 9

8. Petiole with spines more-or-less subequal or with

middle spine shorter than lateral pair (Fig 11G) ..... *Myrmothrinax aequalis*-group (in part)

Petiole with middle spine distinctly longer than lateral pair that are sometimes rudimentary ..... *Myrmothrinax thrinax*-group (in part)

9. Pronotal humeri produced into broad, horizontal, dorsally flattened spines (Fig. 9A); dorsum of petiole acute with pair of intercalary teeth ..... *Myrmhopla cryptoceroides*-group (only *P. cryptoceroides* Emery)

Pronotal humeri produced into rather slender, acute spines; dorsum of petiole with posteriorly sloping platform, without intercalary teeth ..... *Hedomyrma*

10. Propodeum with short, upturned teeth 11

Propodeum with posteriorly directed, horizontal spines 13

11. Petiole scale-like; dorsum armed with four, more-or-less subequal teeth ... *Myrma zopyra*-group (only *P. zopyra* Fr. Smith)

Petiole columnar; dorsum armed with spines and/or teeth of various configurations..... 12

12. Dorsum of petiole with two elevated spines, or with two horizontal spines and often a pair of intercalary teeth (Figs 7A, B, 7C, D)... *Myrmatopa flavicornis*-group

Dorsum of petiole with three very short, erect spines, middle spine often rudimentary (Fig. 12E-F) ... *Myrmothrinax* (in part) (only *P. trispinosa* Fr. Smith)

13. Pronotal humeri rounded or weakly obtusely angulate; petiole with 3 spines,middle spine distinctly elongated, lateral spines short or rudimentary; body without long hairs (Fig. 12G-H).... *Myrmothrinax* (in part) (only *P. unicuspis* Emery)

Pronotal humeri distinctly toothed; petiole with 2 horizontal spines conforming to shape of gaster; body with abundant long hairs (Fig. 1A-B).... *Chariomyrma*

14. Mesosomal dorsum partly marginate (*Myrmatopa*, in part) 15

Mesosomal dorsum totally immarginate 16

15. Lateral margins of mesonotum produced into distinct dorsolateral prominences (Fig. 11B); pronotal dorsum without trace of lateral margins ... *Myrmatopa schang*-group

Lateral margins of mesonotum relatively flat, without distinct dorsolateral prominences (Fig. 11D); pronotal margins evident only at humeral angles, vague or completely lacking posteriorly.... *Myrmatopa wallacei*-group

16. Mesonotum with pair of spines ..... *Polyrhachis* (only *P. erosispina* Emery)

Mesonotum without spines..... 17

17. Mesosoma strongly longitudinally and transversely convex; colour black, mostly highly polished ... 18

Mesosoma weakly to moderately convex; colour of body variable, never highly polished 19

18. Petiole scale-like; dorsum armed with four teeth or spines of various configurations (Fig. 1C, E); sides of head with longitudinal carinae separating genae from ventral parts of head; propodeum without spines..... *Cyrtomyrma*

Petiole columnar; dorsum armed with two horizontal spines that conform to shape of gaster (Fig. 10A, G); sides of head without longitudinal carinae; propodeum with pair of spines ..... *Myrmhopla mucronata*-group

19. Head and body with numerous, more-or-less erect hairs .....20.

Head and body with only a few scattered hairs .. 22

20. Larger species (HL >2.50) .. *Myrmhopla sexspinosa*-group

Smaller species (HL <2.20) 21

21. Frontal carinae distinctly elevated; head and body rather coarsely sculptured (Fig. 8G-H) .... *Myrmhopla cleophanes*-group

Frontal carinae not distinctly elevated; head and body reticulate-punctate ..... *Myrmhopla bicolor*-group

22. Antennal scapes and tibiae distinctly flattened ..... *Myrmhopla hector*-group

Antennal scapes and tibiae not distinctly flattened 23

23. Pronotal humeri produced into distinct, acute spines; head appears normal in relation to rest of body; eyes convex (Figs 8C) 24

Pronotal humeri toothed; head disproportionally large compared to rest of body; eyes flat (Fig. 9C) .. *Myrmhopla flavoflagellata*-group (only *P. storki* sp. nov.)

24. Head and body deeply sculptured, foveolate-rugose (Figs 9E-F)..... 25

Head and body only weakly reticulate-punctate.....26

25. Smaller species (HL <1.60); body light to very dark reddish-brown with appendages distinctly lighter .... *Myrmhopla furcota*-group (only *P. rufipes* Fr. Smith)

Larger species (HL >2.25); body, including apendages and gaster often very dark reddish-brown .. *Myrmhopla armata*-group (only *P. armata* (Le Guillou)

26. Propodeal spines with their tips distictly curved outwards .....*Myrmhopla dives*-group (only *P. dives* Fr. Smith)

Propodeal spines with their tips straight .....*Myrmhopla armata*-group (in part)

LIST OF *POLYRHACHIS* OF SULAWESI

Subgenus **Chariomyrma** Forel, 1915

KEY TO *CHARIOMYRMA* SPECIES (based on workers)

1. Pronotal humeri toothed (Fig. 1A); propodeal spines relatively short, mostly straight, distinctly diverging ..... *arcuata* (Le Guillou)

Pronotal humeri narrowly rounded; propodeal spines longer, weakly curved posteriorly, subparallel, with tips curved weakly outwards (in copal)... *inclusa* Viehmeyer

1. **Polyrhachis arcuata** (Le Guillou, 1842) (FIG. 1A-B)

Formica arcuata Le Guillou, 1842: 315. Syntype queen, worker. Type locality: BORNEO (for queen), NORTH AUSTRALIA (for worker) (locality for worker evidently erroneous), ?MNHN (types presumed lost).

(For full synonymy citations see Kohout, 1998: 510).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 00°34'N, 123°54'E, nr Tumpah R., c. 220m, 11-19.xi.1985 (Malaise trap) (C.van Achterberg) (w); ditto, Rentice II, 210m, 27.x.1985, primary for. (Bosmans & Van Stalle #044) (w) . SULAWESI TENGGARA: Watuwila, 2km E of Base Camp, 12-15.x.1989 (Malaise trap) (C. van Achterberg) (w).

REMARKS. Specimens from Sulawesi are virtually identical and undoubtly conspecific with material of *P. arcuata* from Peninsular Malaysia, Borneo and Sumatra.

2. Polyrhachis inclusa Viehmeyer, 1912

Polyrhachis inclusa Viehmeyer, 1912: 13, fig. 18. Holotype worker. Type locality: INDONESIA, SULAWESI (in copal), SNSD.

REMARKS. Emery (1925) and Bolton (1995) erroneously listed the provenance of *P. inclusa* as New Guinea, probably because the original description was published in a paper entitled "Ameisen aus Deutsch Neuguinea". However, Viehmeyer (1912: 13) clearly stated: "Der *antennata* sehr nahe verwandt ist eine in Kopal eingeschlossene neue Art von Celebes: 33. *Polyrhachis inclusa* sp. nov. (Fig. 18)", followed by its description.

Subgenus Cyrtomyrma Forel, 1915

KEY TO *CYRTOMYRMA* SPECIES (based on workers)

1. Pronotal humeri toothed or angular; propodeal declivity more-or-less oblique 2

   Pronotal humeri narrowly rounded; propodeal declivity virtually vertical; body jet-black (Figs 1C,D) ..... *fornicata* Emery

2. Dorsal petiolar spines distinctly shorter than lateral pair; body black, lightly sculptured (Fig. 1E-F).. *gibosa* Emery

   Dorsal petiolar spines distinctly longer than lateral pair; body jet-black (in copal) ..... *celebensis* Viehmeyer

3. Polyrhachis celebensis Viehmeyer, 1913

Polyrhachis rastellata var. *celebensis* Viehmeyer, 1913: 155. Syntype workers. Type locality: INDONESIA, SULAWESI (in copal), MNHU (examined).

Polyrhachis celebensis Viehmeyer. Kohout, 2006b: 90.

REMARKS. Viehmeyer described *P. celebensis* as a variety of *P. rastellata* and his opinion was accepted by Donisthorpe (1938). However, following the examination of both available syntypes Kohout (2006b) raised *P. celebensis* to specific status.

Polyrhachis celebensis is very similar to *P. fornicata* as redescribed below. Both species have a virtually identical petiole with slender and acute dorsal spines with their tips curved backwards, while the lateral spines are very short, reduced to mere angles. In lateral view the mesosoma of both species is quite similar, featuring a moderately convex pronotum and a distinct step in the mesosomal outline, indicating the position of the metanotal groove. However, the propodeal declivity in *P. celebensis* is steeply oblique, while in *P. fornicata* it is virtually vertical. The main difference between the species is the shape of their pronotal humeri that, in *P. celebensis* are somewhat angulate, while in *P. fornicata* they are narrowly rounded. Considering the wide range of variability in the shape of the humeral angles seen in some other *P. (Cyrtomyrma)* species, such as *P. australis* Mayr, 1870 (Kohout, 2006: 93), it is possible that *P. celebensis* and *P. fornicata* are conspecific. However, without the possibility of examining the type material of *P. fornicata*, this cannot be confirmed.

4. Polyrhachis fornicata Emery, 1900 (FIG. 1C-D)

Polyrhachis rastellata subsp. *fornicata* Emery, 1900: 720. ?Syntype workers. Type locality: INDONESIA, SULAWESI (E. Modigliani), MCSN (type/s considered lost).

Polyrhachis fornicata Emery. Donisthorpe, 1938:261.

This species was originally described from Sulawesi by Emery (1900) as a subspecies of *P. rastellata* and also listed from the island the following year (Emery, 1901). The type specimen/s from Sulawesi should be lodged in the Emery collection in MCSN, however, an extensive search by Dr Roberto Poggi and the author failed to locate them in that, or any other collection examined. Consequently, specimens collected by Elio Modigliani on Sumatra, Engano (= Pulau Enggano) and Mentawei (= Kepulauan Mentawai), lodged in MCSN and labelled as 'Co-types', have been generally accepted as syntypes of this species. These specimens were listed in the original description (Emery, 1900) and bear identification tags inscribed '*Polyrhachis rastellata fornicata* Em' in Emery's handwriting. However, I have directly compared the 'Co-type' specimens from Sumatra (Balighe, x.90-iii.91, E. Modigliani) with recently aquired *Cyrtomyrma* specimens from Sulawesi (see below) and am confident that they represent two different species. The original description of *P. fornicata*, though rather short, is diagnostic and no other *Cyrtomyrma* species known to occur on Sulawesi share the characters given by Emery.

Donisthorpe (1938) regarded *P. fornicata* as a good species, but misinterpreted the short original description by stating that it differed from *P. rastellata* in "the inner teeth of the scale being less high and acute, and less distant from the lateral ones". However, Emery in the original description states that: "La *rastellata fornicata* [worker symbol] differisce dalla forma tipica per i

denti mediali della squama più alti ed acuti, quasi spiniformi, ravvicinati fra loro e più distanti dai denti laterali.". Emery's dignosis describing the middle petiolar spines translates as "middle teeth of the scale higher and more acute, almost spine-like", the direct opposite to Donisthorpe's statement. As a result of Donisthrope's mistranslation, this species has largely been misunderstood and misindentified, with Than (1978) ultimately considering *P. fornicata* a synonym of *P. rastellata*.

The following redescription of *P. fornicata* is given to assist its identification and to establish its identity in relation to the other Sulawesian *Cyrtomyrma*.

MATERIAL. SULAWESI TENGAH: Lore Lindu NP., Toro, Baloli, 835m, 14.iv.2005, cacao agrof., fog. (M.M. Bos #26) (w); ditto, Watu Bohe, 860m, 14.iv.2005, cacao agrof., fog. (M.M. Bos). SULAWESI SELATAN: Kayulagi nr Mangktana, 02°23'S, 120°47'E, 400m, 20.x.1999 (K. Ogata & K. Masaoka #80) (w); Rantepao, Tana Traja, 02°59'S, 119°54'E, 750m, 18.x.1999 (K. Ogata & K. Masaoka #56) (w).

REDESCRIPTION. *Worker*. Dimensions: TL c. 6.00-6.50; HL 1.53-1.62; HW 1.50-1.65; CI 98-100; SL 1.78-1.96; SI 119-121; PW 1.18-1.34; MTL 2.09-2.25 (4 measured).

Anterior clypeal margin produced into a shallow, truncate, medially notched flange, flanked by distinct acute angles. Clypeus in profile weakly convex; medially with blunt, longitudinal carina; basal clypeal margin weakly impressed medially, not impressed laterally. Frontal triangle indistinct. Frontal carinae with margins moderately raised medially; weakly converging and rather flat posteriorly; central area concave with weakly impressed, short, frontal furrow. Sides of head in front of eyes converging towards mandibular bases in almost straight line; behind eyes sides rounding abruptly into convex occipital margin. Eyes convex, in full face view clearly breaking lateral cephalic outline. Ocelli lacking; their relative positions indicated by distinct punctures in sculpturation. Pronotal dorsum in dorsal view with greatest width just behind narrowly rounded humeri; moderately convex in lateral view with promesonotal suture well impressed; position of metanotal groove indicated by distinct step in outline and a shallow depression. Propodeal dorsum rounding smoothly into vertical, declivity. Petiole with anterior face virtualy flat, posterior face weakly convex; dorsal spines situated close together, slender and acute, somewhat diverging with their tips curved backwards; lateral spines very short, reduced to mere angles in some specimens. Subpetiolar process in lateral view relatively short, acute anteriorly, with posterior face weakly concave. Anterior face of first gastral segment lower than full height of petiole, widely rounding onto dorsum of gaster.

Mandibles very finely rugose with numerous piliferous pits. Head, mesosoma and gaster shagreened; intensity of sculpturation only marginally increasing laterally, becoming somewhat reticulate, with meso- and metapleurae and base of petiole only weakly reticulate-rugose. Whole body with numerous piliferous pits and shallow punctures.

Mandibular masticatory borders near outer margins with numerous, curved hairs. Anterior clypeal margin with three, relatively long, anteriorly directed setae medially and a few, short setae laterally. Only a few pairs of rather short, erect hairs near anterior and basal clypeal margins, along frontal carinae and a pair of longer hairs on vertex. A few longer, erect hairs on anterior and posterior faces of fore coxae. Gaster with several erect hairs along posterior margins of dorsal segments and longer and more abundant hairs over ventral surfaces.

Colour. Black throughout, only tips of mandibular teeth, antennal condylae, extreme tip of apical funicular segments, joints of trochaters and femora, and tarsal claws lighter, yellowish- or reddish-brown.

Sexuals and immature stages unknown.

REMARKS. *Polyrhachis fornicata* is apparently endemic to Sulawesi. The 'Co-type' specimens from Sumatra and Mentawei (MCSN, Emery coll.) mentioned above are in my opinion conspecific with *P. rastellata* (see above under nomenclatural changes to extralimital taxa).

5. Polyrhachis gibba Emery, 1901
(FIG. 1E-F)

Polyrhachis gibba Emery, 1901: 580, fig. E. Holotype worker. Type locality: INDONESIA, SULAWESI (H. Fruhstorfer), MCSN (examined).

REMARKS. As the name suggests, *P. gibba* is characterised by a highly arched (gibbose) mesosomal dorsum. The holotype and two additional specimens, putatively identified as *P. gibba* (Than, 1978), from the Andaman Islands (BMNH) and the Philippines (MCZC) were the only known specimens of this species. However, the recent fogging activities of M.M. Bos in Lore Lindu NP (Baloli, Gn. Kalabul,

Kaha) and surrounging agrieultural land (eacao agrof.) provided several additional specimens of this rare species.

Subgenus **Hedomyrma** Forel, 1915

KEY TO *HEDOMYRMA* SPECIES
(based on workers)

1. Distinctly bicoloured: head and tarsi black with mesosoma, petiole and femora light reddish-brown; gaster and tibiae distinctly darker ..... *fervens* Fr. Smith

Unicoloured; black throughout (in copal) ..... *circumdata* Viehmeyer

6. Polyrhachis circumdata Viehmeyer, 1913

Polyrhachis circumdata Viehmeyer, 1913: 152, fig. Syntype workers, queen. Type locality: INDONESIA, SULAWESI (in copal), MNHU (workers examined).

Polyrhachis atropos var. *circumdata* Viehmeyer, 1914: 52.

Polyrhachis circumdata Viehmeyer. Kohout, 1998: 514.

REMARKS. The syntype workers and queen of *P. circumdata*, reeorded from copal, are the only known specimens. For notes on *P. circumdata* and the very similar *P. atropos* Fr. Smith see Kohout (1998).

7. Polyrhachis fervens Fr. Smith, 1860

Polyrhachis fervens Fr. Smith, 1860b: 101, pl. 1, fig. 26. Holotype worker. Type locality: INDONESIA, Ambon I. (A.R. Wallace), OXUM (examined).

Polyrhachis valerus Fr. Smith, 1861:40, pl. 1, fig. 10. Holotype worker. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined). Synonymy by Kohout, 1988: 434.

(For full synonymy citations see Kohout:1988: 434).

REMARKS. The distribution of *P. fervens* extends from eastern Indonesia (Halmahera, Seram and Ambon Is) to New Guinea and south to Cape York Peninsula, Queensland. Apart from the holotype of *P. valerus*, I have seen only one additional speeimen (MNHU) of this speeies from Sulawesi. It bears a hand written tag stating: "Kopal angeblich, Celebes, Prof. O. Sehlaginhaufen?" (name illegible).

Subgenus **Myrma** Billberg, 1820

Myrma was divided by Emery (1925) into five species-groups, two African (*laboriosa* and *viscosa-decemdentata*), two South East Asian (*abrupta* and *zopyrus*) and one widespread (*militaris-relucens*). In his revision of the Afrotropical speeies, Bolton (1973) recognised six speeies-groups (*alexisi, gamaii, militaris, monista, revoili* and *viscosa*), all pertinent to the Ethiopian region. The Australian *Myrma* fauna was reviewed by Kohout (1989), who included all species in the *reluceus* species-group. However, he later (1998) introdueed the *continua* speeies-group, but did not provide a diagnosis, which I reetify here. The *coutinua*-group is characterised by an evenly convex mesosomal outline and the presenee of postocular and lateral ridges on the head. The *inermis* speeies-group was introdueed by Bolton (1974). Included in the group were several species placed by Emery (1925) within the very similar *zopyra*-group. Both speeies-groups inelude some of the smallest members of the subgenus. The *inermis*-group is charaeterised by well developed pronotal spines, a petiole with two short lateral spines and an entire, areuate dorsal petiolar margin, and by elosely approximated frontal earinae producing an extremely narrow central area. In contrast, species ineluded here within the *zopyra*-group have the pronotal spines reduced to mere teeth, a petiole armed with four, more-or-less distinet teeth and more widely separared frontal carinae and a broader central area. Twenty-seven Sulawesian species of *Myrma* belong within the *relucens* species-group, two in the *inermis*-group and one species eaeh in the *continua*- and *zopyra*-groups. In addition, the island also has several endemie *Myrma* species that eonstitute a new *vestita* species-group characterised by a seale-like petiole that lacks spines and has a dorsal margin with only blunt teeth or a shallow median emargination. This petiolar eonfiguration resembles that of *P. abrupta* Mayr, 1867 from Halmahera, but this speeies differs from those of the *vestita*-group in having strongly truncate eyes and a distinct earina running from the eyes towards the oeeipital eorners. A petiole lacking dorsal spines is also eharaeteristie of the *inermis*-group, but its eonstituent speeies differ from those of the *vestita*-group in having their dorsal petiolar margin smooth and entire. In addition, members of the *vestita*-group are some of the largest species of *Myrma*, while the *inermis*-group ineludes some of the smallest.

Polyrhachis continua speeies-group

8. Polyrhachis continua Emery, 1887

Polyrhachis continua Emery, 1887: 235, pl. 4, fig. 21. Holotype worker. Type locality: INDONESIA, Ternate I., Aqui Conora (O. Beccari), MCSN (examined).

Polyrhachis continua var. *revocata* Viehmeyer, 1913: 151. Syntype workers. Type locality: INDONESIA, SULAWESI (in copal), MNHU (examined). Synonymy by Kohout, 1998: 519.

REMARKS. The syntypes of *P. continua revocata* appear to be the only speeimens of this species

recorded from Sulawesi. *Polyrhachis continua* is known from the Moluccas (Ternate I.) and New Guinea (Paumomu R.), with other species of the *continua*-group extending to the Bismarck Archipelago and south to Cape York Peninsula in Queensland. Like other members of the species-group, *P. continua* has an evenly curved mesosomal dorsum that lacks a distinct border between the propodeal dorsum and declivity, and has postocular and lateral ridges on the head (Kohout, 1989; 1998).

Polyrhachis inermis species-group

KEY TO *INERMIS*-GROUP SPECIES (based on workers)

1. Black throughout ..... *inermis* Fr. Smith

   Body black; tibiae light to medium reddish-brown with rest of legs distintly darker ..... *orsylla* Fr. Smith

9. Polyrhachis inermis Fr. Smith, 1858 (FIG. 1G-H)

Polyrhachis inermis Fr. Smith, 1858: 68, pl. 4, figs 25, 26. Holotype worker. Type locality: INDONESIA, SULAWESI, BMNH (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 400m, 11.ii.1985, fog. (N.E. Stork et al.) (w); ditto, 230m, 11.vii.1985, fog. (N.E. Stork et al.) (w); ditto, 2.xii.1985, fog. (N.E. Stork et al.) (♀); ditto, subcamp Barney's, 300m, x.1985 (Bosmans & Van Stalle #022) (♀); ditto, Maze area, 210m, 27.x.1985, sweeping (Bosmans & Van Stalle #057) (w); ditto, Toraut, 200m, 11.x.1985 (Bosmans & Van Stalle #020) (♀); ditto, 8.x.1985 (Bosmans & Van Stalle# 010) (w). SULAWESI TENGAH: nr Luwuk, Salodik-Linyek, 500m, 21.-31.x.1989 (Malaise trap) (C.van Aehterberg) (w). SULAWESI TENGGARA: 1-2km E of Wolasi, 42km S Kandari, e. 350m, rf, 13-14.vii.1972 (W.L. Brown) (w). SULAWESI SELATAN: Bantimurung, Ujung Pandang, 8.vii.1992 (Sk. Yamane) (w).

REMARKS. The holotype worker of *P. inermis* is very similar to specimens from Dumoga-Bone NP and other recently collected material from elsewhere in Sulawesi. However, the modern specimens are generally more slender than the holotype, due to a narrow pronotal dorsum. Their pronotal spines are also slightly less divergent, with the lateral pronotal margins at the bases of spines less emarginate. In addition they have rather distinct longitudinal striation on the mesosomal dorsum which is rather vague in the holotype, notably on the pronotal dorsum. The eyes are fairly convex in the holotype and clearly exceed the outline of the head in full face view, while in most of the recently collected specimens the eyes do not, or only marginally, exceed the lateral cephalic outline. Despite these differences, the recent specimens are very similar to the holotype in most other aspects and I consider them conspecific.

Polyrhachis inermis, together with *P. carbonaria* Fr. Smith, *P. ceramensis* Mayr, *P. hosei* Donisthorpe, *P. orsylla* Fr. Smith, *P. ritsemai* Mayr, *P. vindex* Fr. Smith, and about ten undescribed new species from Borneo, form the distinct *inermis*-group (Bolton, 1974). The synonymy of *P. carbonaria* and *P. hosei* was discussed recently (Kohout, 1998) while the status of the remaining species appears to be clearly delimited, except for *P. orsylla*, which is discussed below.

10. Polyrhachis orsylla Fr. Smith, 1861

Polyrhachis orsyllus Fr. Smith, 1861: 39, pl. 1, figs 6, 7. Holotype worker. Type locality: INDONESIA, SULAWESI (A.R. Wallace), OXUM (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 400m, 11.ii.1985, fog. (N.E. Stork) (w). SULAWESI TENGAH: Lore Lindu NP, Toro, Gn. Kalabui, 950m, 16.iv.2005, nat. for., fog. (M.M. Bos #37) (w). SULAWESI SELATAN: Cagar Alam Karaenta, Kabupaten Maros, 265-315m, iii.1996 (B. Gobin) (w); Balampeasoang For., 5-8km NE of Tanete, 400m, degraded rf., 8-10.vii.1972 (W.L. Brown) (w); Sampulage nr Mangktana, 02°16'S, 120°47'E, 1000m, 19.x.1999 (K. Ogata & K. Masaoka #70) (w).

REMARKS. *Polyrhachis orsylla* is undoubtedly closely related to *P. vindex* Fr. Smith and when Wheeler (1919) redescribed the latter, he suggested *P. orsylla* could represent a subspecies or synonym of *P. vindex*. Later Wheeler (1924) listed *P. orsylla* as a synonym of *P. vindex*, a decision followed by Bolton (1974) and Dorow (1995). However, Emery (1925), Karawajew (1927) and more recently Bolton (1995) listed *P. orsylla* as a separate species and I am inclined to follow their opinion. The species differ in the form of the pronotal spines which are shorter and only slightly longer than their basal widths in *P. orsylla* and about twice as long as their basal widths in *P. vindex*. Also, the sculpturation of pronotal dorsum in *P. orsylla* is distinctly finer, almost vague in some specimens, while in *P. vindex* it consists of rather distinct, more-or-less regular, striation. Both species are rather uncommon and represented by single specimens or short series in collections. *Polyrhachis orsylla* could ultimately be confirmed as an isolated population of *P.vindex* but this requires examination of worker-queen associated series

from across the range of their distribution, material that is not presently available.

Polyrhachis relucens species-group

KEY TO *RELUCENS*-GROUP SPECIES (based on workers)

1. Distinctly bicoloured with body mostly black and legs, at least in part, orange or light red 2

   Unicoloured; black throughout with only legs sometimes dark to very dark reddish-brown 4

2. Petiole without spines or teeth, obtusely angular; femora, petiole and base of gaster light reddish-brown ..... *rufofemorata* Fr. Smith

   Petiole with spines, teeth or both in various configurations; legs distinctly orange or light red 3

3. Whole body, including appendages with abundant, short to medium length hairs and somewhat untidy, relatively long appressed pubescence; propodeal dorsum with upturned teeth; declivity oblique ..... *compressicornis* Fr. Smith

   Head, mesosoma, petiole and gaster covered with short to medium length hairs and closely appressed pubescence that is completely absent from legs; propodeal dorsum without teeth; declivity very steep, virtually vertical ..... *ithona* Fr. Smith

4. Antennal scapes with bases distinctly broadened and strongly bent (Fig. 6A) ..... *bosi* sp. nov.

   Antennal scapes without bases broadened, straight.... 5

5. Smaller species (HL <2.00) 6

   Larger species (HL >2.00) 9

6. Body very finely sculptured, highly polished, jet-black; medium length hairs scattered over most surfaces; closely appressed pubescence lacking (Fig. 3A-B) ..... *cybele* Wheeler

   Body reticulate-punctate, opaque below abundant, closely appressed pubescence 7

7. Dorsum of mesosoma with mesonotum and propodeum virtually flat in lateral view (Fig. 2D); propodeal declivity concave; petiolar spines very short; golden appressed pubescence present over most body surfaces ..... *brachyspina* sp. nov.

   Dorsum of mesosoma evenly convex in lateral view (Fig. 3D); propodeal declivity oblique; appressed pubescence white or silvery 8

8. Petiole rather robust, distinctly biconvex in profile, dorsum with very prominent lateral teeth and short, weakly dorsoposteriorly elevated spines; eyes weakly truncate posteriorly; relatively short hairs over most body surfaces, including legs ..... *numeria* Fr. Smith

   Petiole very slender with only obtusely angular, not prominent, lateral teeth and strongly dorsally elevated spines; eyes not truncate; only a few hairs arising from front of head and gastral apex, hairs completely absent from mesosomal dorsum ..... *festina* sp. nov.

9. Propodeal teeth very prominent, dorsally flattened and curved upwards and outwards (Fig. 3E-F) ..... *hastata* Fr. Smith

   Propodeal teeth not prominent, short or rudimentary (Fig. 3H) 10

10. Dorsum of head and mesosoma rather regularly, more-or-less longitudinally striate..... 11

    Dorsum of head and mesosoma more-or-less uniformly reticulate-punctate without evident longitudinal pattern 16

11. Gaster distinctly, finely, longitudinally striate 12

    Gaster finely reticulate-punctate 14

12. Dorsum of petiole straight with rather distinct intercalary tooth ..... *striatorugosa* Fr. Smith

    Dorsum of petiole 'U'-shaped without intercallary tooth (Fig. 4E) ..... *sculpturata* Fr. Smith

13. Body, including appendages with abundant, medium to long erect hairs..... 15

    Body virtually without hairs, except for a few erect hairs on front of head and around gastral apex (Fig. 3G, H) ..... *isacantha* Emery

14. Gaster reticulate-punctate, opaque; dorsum of petiole with short intercalary tooth (Fig. 4C).... *rixosa* Fr. Smith

    Gaster very finely shagreened, highly polished (in some specimens dorsum of first gastral segment at summit with indication of very fine longitudinal striae); intercalary petiolar tooth acute and rather prominent... *nigropilosa* Mayr

15. Body with distinct, pale or rich golden, closely appressed, abundant pubescence over most dorsal surfaces 17

    Body with very diluted, white or greyish, appressed pubescence, virtually absent from most dorsal surfaces 18

16. Dorsal petiolar spines shorter than distance between their bases; dorsum of petiole with distinct acute intercalary tooth.....*decipiens* Roger

    Dorsal petiolar spines very slender, curved and distinctly longer than distance between their bases; dorsum of petiole without intercalary tooth (Figs 4A, B) ..... *olena* Fr. Smith

17. Pronotal spines virtually straight; petiole with parallel spines and rudimentary intercalary tooth (Fig. 2E) .....*brendelli* sp. nov.

    Pronotal spines curved, bullhorn-shaped; petiole with spines diverging, dorsum without intercalary tooth (Fig. 2G)..... *browni* sp. nov.

11. Polyrhachis bosi sp. nov. (FIGS 2A-B, 6A)

MATERIAL. HOLOTYPE, SULAWESI TENGAH: Lore Lindu NP, Toro, Gn. Kalabui, 950m, 6.v.2005, nat. forest, fog., M.M. Bos (worker). PARATYPE: Lore Lindu NP, Toro, Gn. Kamonua, 1080m, nat. forest, fog., M.M. Bos (worker). Type deposition: Holotype in QM (QMT144145), paratype in GUGG (M. Bos private collection).

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 7.96, 8.32; HL 1.93, 2.09; HW 1.50, 1.65; CI 78, 79; SL 2.15, 2,34; SI 143, 142; PW 1.18, 1.25; MTL 2.28, 2.50 (2 measured).

Anterior clypeal margin arcuate, very narrowly truncate medially. Clypeus with blunt, median carina; in profile almost straight, only weakly raised anteriorly; posteriorly rounding into shallowly impressed basal margin. Frontal triangle indistinct. Frontal carinae sinuate with sharply raised, almost

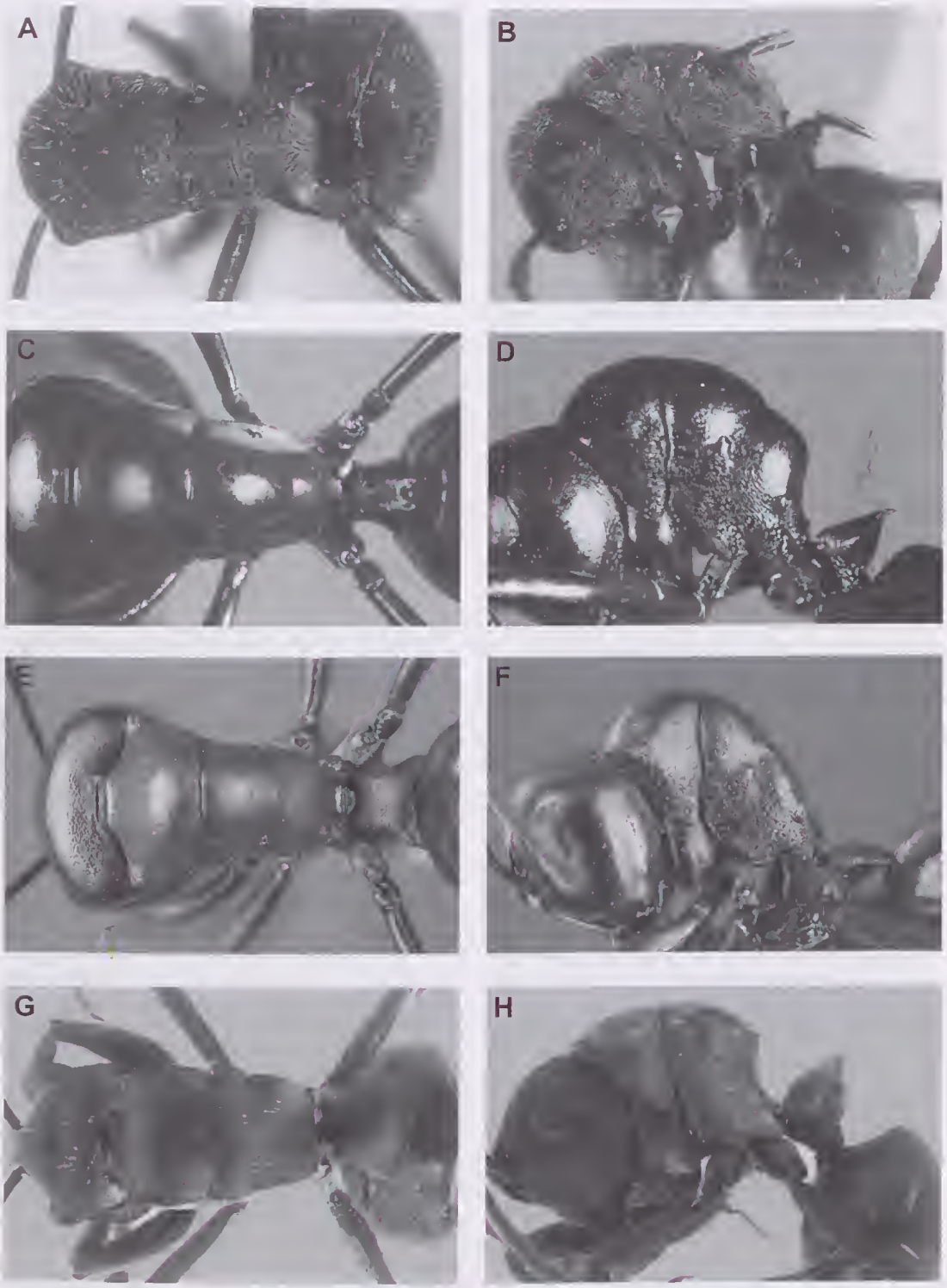

FIG. 1. *Polyrhachis* species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. arcuata* (Le Guillou); C-D, *P. fornicata* Emery; E-F, *P. gibba* Emery; G-H, *P. inermis* Fr. Smith (not to scale).

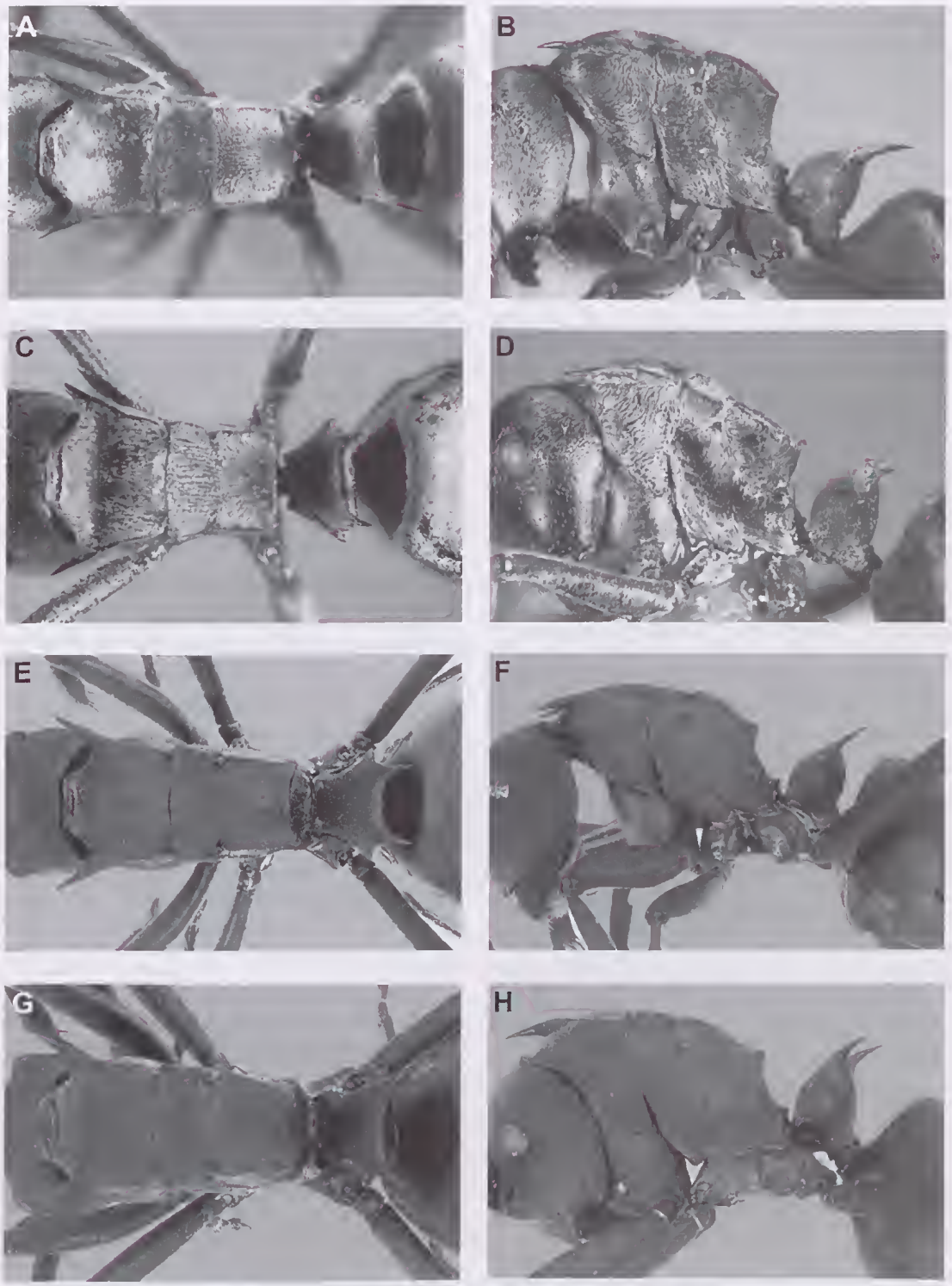

FIG. 2. *Polyrhachis* (*Myrma*) species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. bosi* sp. nov.; C-D, *P. brachyspina* sp. nov.; E-F, *P. brendelli* sp. nov.; G-H, *P. browni* sp. nov. (not to scale).

vertically laminate margins; central area extremely narrow, with clearly indicated median frontal furrow. Antennal scapes relatively short, bases distinctly broadened with excavated inner margins; in dorsal view scapes somewhat twisted and strongly bent (Fig. 6A). Sides of head in front of eyes only weakly converging anteriorly; behind eyes sides rounding into broad occipital margin. Eyes moderately convex, situated well forward from occipital corners; in full face view eyes only marginally breaking lateral cephalic outline. Lateral ocelli poorly developed; position of median ocellus indicated by distinct pit in cephalic sculpturation. Pronotal dorsum virtually flat between pair of rather long, anterolaterally directed, somewhat dorsomedially flattened, acute spines; their outer edges acute and basally continuous with lateral margins of pronotum. Mesonotal dorsum wider than pronotal dorsum at base, strongly transverse, with medially emarginate lateral margins. Propodeal dorsum slightly wider than long, virtually parallel-sided, with weakly sinuate lateral margins terminating in rounded, upturned, transverse ridges that meet medially and form an inwardly bowed carina dividing propodeal dorsum from shallowly concave declivity. Petiole biconvex in profile, armed with a pair of dorsolaterally and posteriorly directed, acute spines that are situated on dorsolateral angles (apex of left petiolar spine in holotype bent weakly, but distinctly inwards); dorsal petiolar margin between spines transverse, with indication of a median intercalary tooth; lateral margins of petiole with secondary, short, acute tooth below bases of spines. Anterior face of first gastral segment concave, with anterodorsal margin reaching height of dorsal petiolar margin.

Mandibles finely, mostly longitudinaly striate. Head, petiole and gaster shagreened; dorsum of mesosoma with weakly indicated longitudinal striae; sides of mesosoma more distinctly sculptured, reticulate-punctate, with reticulae somewhat oblique. Tips of pronotal and petiolar spines rather smooth, polished.

Mandibular masticatory borders and outer margins apically with several semierect, golden hairs. Anterior clypeal margin with a few long, anteriorly directed setae medially and fringe of shorter setae laterally. Several pairs of medium length, erect, golden hairs near anterior and basal margins of clypeus and along frontal carinae; single pair on vertex arising from pits next to lateral ocelli. Antennal scapes with a few, short, erect hairs fringing apex. Pair of downwardly directed, longer hairs on anterior face of fore coxa. Gaster with several medium length hairs on apical segments, their length distinctly increasing towards gastral apex and on ventral gastral surfaces. Most of body with rather dense, closely appressed, mostly silvery pubescense obscuring underlying sculpturation. Pubescence on dorsum of mesosoma follows longitudinal pattern of striation, distinctly longer and irregular pubescence on sides of mesosoma.

Colour. Black throughout.

Sexuals and immature stages unknown.

REMARKS. *P. bosi* is somewhat similar to *P. festina*, but differs in having the base of antennal scapes distinctly widened and strongly bent (Fig. 6A), and the frontal carinae very close together, leaving the central area extremely narrow.

12. Polyrhachis brachyspina sp. nov. (FIG. 2C-D)

MATERIAL. HOLOTYPE, SULAWESI UTARA: Dumoga-Bone NP, 11.ii.1985, N.E. Stork et al. (worker). Type deposition: Unique holotype in BMNH.

DESCRIPTION. *Worker*. Dimensions: TL c. 7.76; HL 1.96; HW 1.62: CI 83; SL 2.25; SI 139; PW 1.22; MTL 2.50.

Anterior clypeal margin arcuate, entire. Clypeus with blunt longitudinal median carina; in profile shallowly concave, with distinctly raised anterior margin and flat basal margin. Frontal triangle distinct. Frontal carinae sinuate, margins weakly raised; central area flat, relatively wide with weakly impressed frontal furrow. Sides of head in front of eyes straight, weakly converging towards mandibular bases; behind eyes sides rounding into broadly convex occipital margin. Eyes moderately convex, in full face view breaking lateral cephalic outline. Ocelli lacking. Pronotal dorsum convex in outline with pair of broad-based, anterolaterally and weakly downwards directed, acute spines; lateral edges of spines continuous with weakly posteriorly converging pronotal margins. Mesonotum wider than long. Propodeum with lateral margins parallel, terminating posteriorly in distinct, upturned denticles; posterior margins meeting medially to form a distinct transverse ridge that separates propodeal dorsum from distinctly concave declivity. Petiole biconvex in profile; armed with a pair of short, acute, dorsolaterally directed, posteriorly curved spines on dorsolateral angles; spines separated by relatively wide, weakly medially convex, dorsal margin; short, acute tooth situated laterally

below base of each spine. Anterior face of first gastral segment concave with rather distinct anterodorsal margin narrowly rounding onto dorsum of segment.

Mandibles longitudinally striate. Clypeus shagreened, sides of head rather reticulate-rugose; vertex and area between frontal carinae and eyes with irregular, mostly longitudinal striae. Central area rugose with distinct punctures; shagreened along occipital margin. Pronotal dorsum shagreened with faint longitudinal striations. Dorsa of mesonotum and propodeum somewhat irregularly, mostly longitudinally, striate-punctate; sides of mesosoma reticulate-punctate. Petiole shagreened dorsally with sculpturation coarser at base. Gaster very finely shagreened.

Mandiblar masticatory borders with several yellow, curved hairs. Anterior clypeal margin with a few, anteriorly directed longer setae and several shorter setae fringing margin laterally. A few pairs of erect, medium length hairs near anterior and basal clypeal margins. Gaster with several, erect, longer hairs, arising along posterior margins of apical segments and around apex. Relatively long, appressed, yellow or golden pubescence in various densities over most dorsal body surfaces, but virtually absent from central area, vertex, sides of head and between frontal carinae and eyes. Pubescence on gaster distinctly shorter, more appressed and dense, almost completely hiding underlying sculpture.

Colour. Black throughout; only tips of mandibular teeth, extreme tips of apical funicular segments and tarsal claws, light reddish-yellow.

Sexuals and immature stages unknown.

REMARKS. *Polyrhachis brachyspina* is characterised by a rather short mesosoma with broadly-based pronotal spines and very short petiolar spines.

13. Polyrhachis brendelli sp. nov.
(FIG. 2E-F)

MATERIAL. HOLOTYPE: SULAWESI TENGAH, nr Morowali, Ranu R. area, 27.i.-20.iv.1980, M.J.D. Brendell (B.M. 1980-280) (worker). PARATYPES: data as for holotype (23 workers). Type deposition: Holotype and most paratypes (10) in BMNH, 2 paratypes each in AMNH, ANIC, CASC, MCZC, QM, RMNH and NMNH. OTHER MATERIAL. SULAWESI TENGGARA: nr Sanggona, Base Camp, Gn Watuwila, c. 200m, 15.x-5.xi.1989 (Malaise trap) (C.van Achterberg) (w); ditto, 12-15.x.1989 (Malaise trap) (C.van Achterberg) (w); Wolasi, Pangalulu, 04°10'S, 122°30'E, 140m, 14.x.1999 (K. Ogata & K. Masaoka #52) (w). SULAWESI TENGAH: Lore Lindu NP, Toro, Kauboga, 840m, 15.iv.2005, caeao agrof., fog. (M.M. Bos #33) (w). SULAWESI SELATAN: Balampesoang Forest, 5-8km NE of Tanete, 400m, vii.1972, degraded rf. (W.L. Brown) (w).

DESCRIPTION. *Worker.* Dimensions (holotype cited first): TL c. 9.22, 8.77-9.73; HL 2.28, 2.25-2.40; HW 1.75, 1.68-1.81; CI 77, 73-77; SL 2.84, 2.74-2.96; SI 162, 161-169; PW 1.31, 1.26-1.36; MTL 3.18, 3.12-3.48 (24 measured).

Anterior clypeal margin arcuate, very weakly and narrowly truncate medially. Clypeus with blunt but distinct median carina; in profile clypeus sinuate with elevated anterior margin, basal clypeal margin almost flat, laterally indicated by a thin line breaking sculpturation. Frontal triangle distinct. Frontal carinae sinuate with moderately raised, laminate margins; central area concave anteriorly, flat posteriorly with distinct frontal furrow. Sides of head in front of eyes almost straight, weakly rounding into mandibular bases; behind eyes sides rounding into broad occipital margin. Eyes moderately convex, situated well forward from occipital corners; in full face view only marginally breaking lateral cephalic outline. Ocelli lacking. Pronotal dorsum with pair of acute, dorsolaterally and weakly downwards directed, somewhat dorsally flattened spines; lateral margins of spines acute and continuous with lateral margins of pronotum. Dorsum of mesonotum transverse, rather flat with weakly raised, posteriorly converging lateral margins. Propodeum with lateral margins weakly converging posteriorly and terminating in distinct, narrowly rounded, upturned ridges; posterior margins of ridges meeting medially, forming a virtually straight line separating propodeal dorsum from declivity. Petiole biconvex in profile, with two, posterodorsally directed spines; dorsal margin between spines concave with blunt intercalary denticle; lateral margin of petiole below base of each spine with a secondary, short, acute tooth. Anterior face of first gastral segment weakly concave with anterodorsal margin narrowly rounding onto dorsum of segment.

Mandibles rather polished, very finely striate with piliferous pits. Body finely and closely reticulate-punctate, opaque; dorsum of mesosoma with some reticulae irregularly, mostly longitudinally directed (evident under certain angles of lighting). Gastral sculpturation distinctly finer than on mesosoma, regularly reticulate-punctate.

Only a very few, curved, golden hairs at mandibular masticatory borders. Anterior clypeal margin with several long, anteriorly directed, golden setae medially. A few pairs of erect, medium length hairs on clypeus, along frontal carinae and single pair of anteriorly directed hairs on vertex. Only a few, relatively long, erect hairs lining posterior margins of apical gastral segments. Very short, appressed, white or greyish pubescence, rather diluted and not concealing underlying sculpturation, on most body surfaces.

Colour. Head, mesosoma and petiole black; mandibular masticatory borders, distal ends of antennal scapes and extreme tip of apical funicular segments reddish-brown; legs lighter, reddish-brown, except for bases of tibiae and tarsal segments that are distinctly darker. Dorsum of gaster reddish-brown with ventral surfaces distinctly lighter.

Sexuals and immature stages unknown.

REMARKS. *Polyrhachis brendelli* is a characteristic species that resembles *P. browni* sp. nov. and *P. olena* Fr. Smith, also described from Sulawesi, but is clearly distinct. *Polyrhachis brendelli* differs from *P. browni* by its much finer body sculpturation and in the shape of the pronotal spines. In *P. brendelli* the spines are anterolaterally directed and virtually straight. Those in *P. browni* are distinctly longer, more slender, bullhorn-shaped and project more laterally before curving anteriorly at mid length. Moreover, the spines in *P. brendelli* are somewhat dorsally flattened while in *P. browni* they are more-or-less rounded in cross-section. Also, the posterior ridge separating the propodeal dorsum from the declivity is virtually straight or only weakly bowed in *P. brendelli*, while it is more deeply bowed inwards in *P. browni*. The petiolar spines in *P. brendelli* are virtually parallel and the dorsal petiolar margin bears an intercalary denticle. In *P. browni*, the dorsal petiolar spines are much shorter, strongly diverging and more widely separated; and the dorsal petiolar margin lacks any trace of an intercalary tooth. Both species differ from *P. olena* by their distinctly opaque, closely reticulate-punctate body sculpturation that is not hidden by rather diluted pubescence. In contrast all body surfaces in *P. olena* are shagreened with the sculpturation mostly hidden by relatively dense, appressed pubescence. *Polyrhachis olena* also differs from *P. brendelli* and *P. browni* by a distinctly narrower mesosomal dorsum, particularly the propodeum, and by its more elongated petiolar spines.

14. **Polyrhachis browni** sp. nov.
(FIG. 2G-H)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Dumoga-Bone NP, 2.xii.1985, fog., N.E. Stork et al. (worker). PARATYPES: data as for holotype (worker); ditto, 11.vii.1985, fog., N.E. Stork et al. (2 workers) ditto, 25.ii.1985, N.E. Stork et al. (4 workers); ditto, 230m, 10.ii.1985, fog., N.E. Stork et al. (worker); Type deposition: Holotype and 2 paratypes in BMNH, 1 paratype each in ANIC, CASC, MCZC, QM. OTHER MATERIAL. SULAWESI UTARA: Mt Tangkoko-Batuangus Res., 10-200m, vi.1972, tropical evergreen for. (W.L. Brown) (w); Mt Klabat, SW slope, 400-600m, rf., 13-19.vi.1972 (W.L. Brown) (w). SULAWESI: 27.ii-4.xii.1984 (no further data) (w).

DESCRIPTION. *Worker.* Dimensions (holotype cited first): TL c. 9.42, 8.87-9.47; HL 2.40, 2.28-2.43; HW 1.75, 1.67-1.76; CI 73, 71-74; SL 2.99, 2.93-3.06; SI 171, 172-178; PW 1.40, 1.26-1.41; MTL 3.58, 3.43-3.73 (9 measured).

Anterior clypeal margin arcuate, entire. Clypeus with blunt, longitudinal carina medially; sinuate in profile with elevated anterior margin; basal clypeal margin weakly impressed, laterally indicated by a thin line breaking sculpturation. Frontal triangle distinct. Frontal carinae sinuate with laminate margins that are elevated anteriorly and posteriorly flat; central area concave anteriorly, with distinct frontal furrow. Sides of head in front of eyes straight, weakly converging towards mandibular bases; behind eyes sides weakly convex and rounding into occipital margin. Eyes convex, situated well forward from occipital corners; in full face view breaking lateral cephalic outline. Ocelli lacking, relative positions indicated by small pits in sculpturation. Pronotal dorsum with long, slender, acute spines that are directed anterolaterally and curve more anteriorly and slightly downwards at mid length. Lateral edges of spines continuous with parallel margins of pronotum. Mesonotum transverse, with raised anterior corners; lateral margins shallowly emarginate medially and rounded posteriorly. Propodeal dorsum with margins distinctly converging posteriorly and terminating in upturned, tooth-like denticles, their posterior margins meeting medially, forming an inward-bowed ridge that separates propodeal dorsum from declivity. Petiole biconvex in profile; armed with a pair of widely separated, dorsolaterally and weakly posteriorly directed, acute spines; dorsal margin between spines weakly concave, more-

or-less acute; lateral margin of petiole below base of each spine with a secondary, short, acute tooth. Anterior face of first gastral segment weakly concave with anterodorsal margin narrowly rounding onto dorsum.

Mandibles finely, mostly longitudinally striate, somewhat polished, with numerous piliferous pits towards bases. Head, mesosoma, including declivity, petiole and gaster reticulate-punctate with sculpturation very fine and rather uniformly distributed over all body surfaces, except pronotal and petiolar spines that are rather smooth and polished.

Mandibular masticatory borders with several curved, golden hairs. Anterior clypeal margin with medium length, anteriorly directed, golden setae and with a few short setae fringing margin laterally. Mostly paired, medium length, erect, yellow and golden hairs near anterior and basal clypeal margins, along frontal carinae and a single pair of hairs on vertex. Gaster with only a few, relatively long, erect hairs at apex and posterior margins of apical segments on venter.

Colour. Black throughout; only extreme tip of apical funicular segments and tarsal claws light reddish-brown.

Sexuals and immature stages unknown.

REMARKS. *Polyrhachis browni* is rather similar to *P. brendelli* with distinguishing characters listed under the latter.

15. Polyrhachis compressicornis Fr. Smith, 1860

Polyrhachis compressicornis Fr. Smith, 1860: 69. Syntype worker, queen. Type locality: INDONESIA, SULAWESI, Makassar (A.R. Wallace), OXUM (examined).

REMARKS. *Polyrhachis compressicornis* appears to be a very rare species that was absent from all recent Sulawesian collections examined. The types in OXUM and a single worker in BMNH are the only specimens I have seen.

16. Polyrhachis cybele Wheeler, 1919 stat. nov. (FIG. 3A-B)

Polyrhachis (Hemioptica) aculeata ssp. *cybele* Wheeler, 1919: 126. Syntype workers. Type locality: BORNEO, SARAWAK, Kuching (J. Hewitt), MCZC (examined).

MATERIAL. SULAWESI TENGAH: Lore Lindu NP, 01°15'S, 120°20'E, nr Dongi-Dongi, c. 1010m, 4.-9.xii.1985 (Malaise trap) (C.van Achterberg) (w). SULAWESI SELATAN: Sampulage nr. Mangkrana, 02°20'A, 120°48'E, 800m, 19.x.1999 (K. Ogata & K. Masaoka) (w).

REMARKS. The characters given by Wheeler (1919) to separate *P. aculeata cybele* from *P. aculeata*, described by Mayr (1879) from India, clearly show the taxa are very distinct. *Polyrhachis cybele* is more robust with thicker and shorter pronotal and petiolar spines in comparison to the more slender *P. aculeata*. The petiole in *P. cybele* is broadly transverse with a distinctly arcuate dorsal edge and has dorsolateral spines that arise obliquely from close to the posterior face of the petiole. As a result, the dorsal edge of the petiole is clearly visible in lateral view. In contrast the dorsal edge of the petiole in *P. aculeata* is less prominent and, in lateral view, is hidden by the more upright and longer and slender dorsolateral spines. I have compared both workers from Sulawesi with the syntypes and other *P. cybele* specimens from Borneo and Sumatra and found them all remarkably similar. The characters separating *P. cybele* from *P. aculeata* are constant across their known distributions and I have no hesitation in elevating *P. cybele* to specific rank.

17. Polyrhachis decipiens Roger, 1863

Polyrhachis decipiens Roger, 1863: 156. Syntype workers. Type locality: INDONESIA, Batjan I., MNHU (examined).

Polyrhachis restituta Viehmeyer, 1913: 149, figs. Syntype workers. Type locality: INDONESIA, SULAWESI (in copal), MNHU (examined).

Polyrhachis restituta var. *conclusa* Viehmeyer, 1913:151, fig. Type locality: INDONESIA, SULAWESI (in copal), MNHU (examined).

REMARKS. Apart from the types of *P. restituta* and *P. restituta conclusa* (both from copal), *P. decipiens* has apparently never been reported from Sulawesi. The above synonymy proposed by Kohout (1998) is supported by the comparison of more recently collected specimens from Halmahera and Batjan Island.

18. Polyrhachis festina sp. nov. (FIG. 3C-D)

MATERIAL. HOLOTYPE: SULAWESI SELATAN, Sampulage nr. Mangktana, 02°16'S, 120°47'E, 1200m, 19.x.1999, K. Ogata & K. Masaoka #67 (worker). Type distribution: Unique holotype in QM (QMT144146).

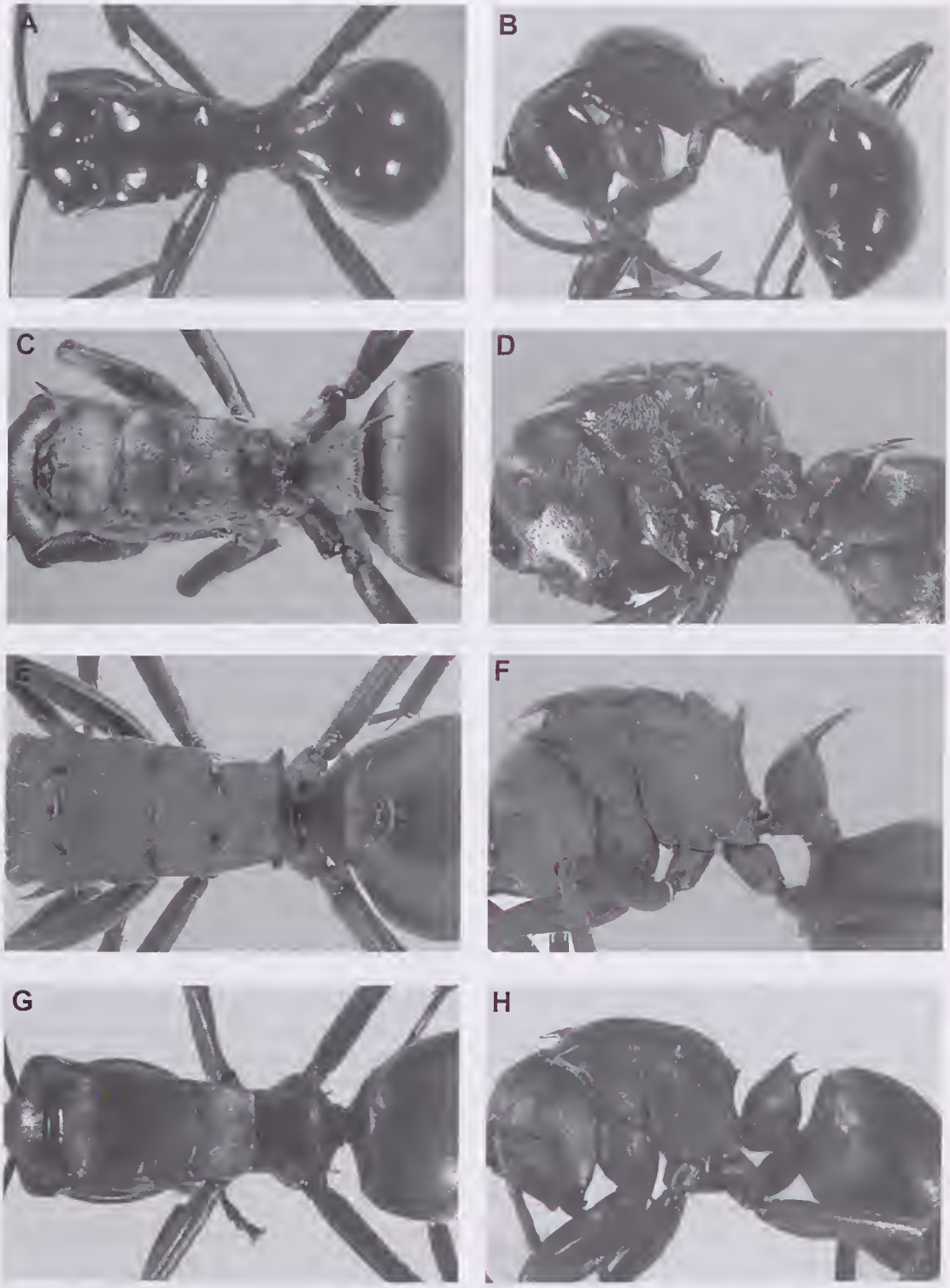

FIG. 3. *Polyrhachis* (*Myrma*) speeies, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. cybele* Wheeler; C-D, *P. festina* sp. nov.; E-F, *P. hastata* (Latreille); G-H, *P. isacantha* Emery (not to seale).

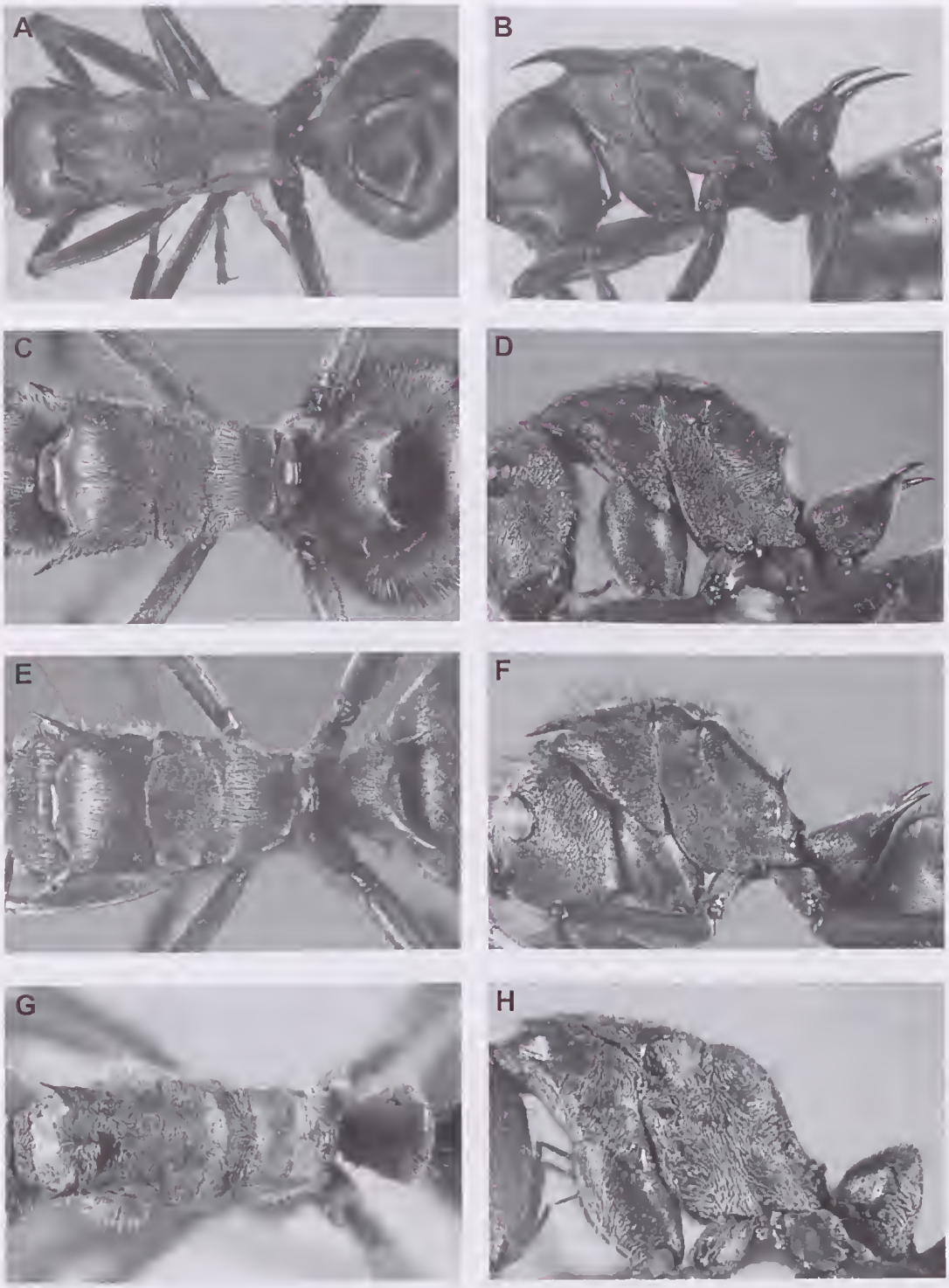

FIG. 4. *Polyrhachis* (*Myrma*) species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. olena* Fr. Smith; C-D, *P. rixosa* Fr. Smith; E-F, *P. sculpturata* Fr. Smith; G-H, *P. gobini* sp. nov. (not to scale).

DESCRIPTION. *Worker*. Dimensions: TL c. 6.80; HL 1.84; HW 1.50; CI 81; SL 2.28; SI 152; PW 1.12; MTL 2.25.

Anterior clypeal margin arcuate, entire. Clypeus with blunt longitudinal carina medially; in profile clypeus very weakly sinuate, rounding posteriorly into shallowly impressed basal margin that is laterally indicated by a thin line breaking sculpturation. Frontal triangle weakly indicated. Frontal carinae sinuate with raised, laminate margins; central area with weakly impressed frontal furrow. Sides of head in front of eyes straight, weakly converging anteriorly and narrowly rounding into mandibular bases; behind eyes sides evenly rounding into convex occipital margin. Eyes convex, in full face view breaking lateral cephalic outline. Ocelli lacking. Pronotal dorsum rather flat between pair of long, anterolaterally and weakly downwards directed, somewhat dorso-medially flattened, acute spines; outer edges of spines acute and continuous with parallel, posteriorly rounded lateral margins of pronotum. Mesonotal dorsum at base wider than pronotal dorsum, strongly transverse, with weakly medially emarginate lateral margins. Propodeal dorsum with lateral margins converging posteriorly and terminating in weakly upturned, short, transverse ridges; propodeal dorsum in profile convex descending into shallowly concave declivity in medially uninterrupted line. Petiole biconvex in profile, armed with a pair of dorsolaterally and posteriorly directed, acute spines that are situated on dorsolateral angles of petiole and separated by a transverse, medially weakly raised, dorsal margin. Lateral margin of petiole below base of each spines with secondary, short, acute tooth. Anterior face of first gastral segment concave, with anterodorsal margin distinctly lower than height of petiole.

Mandibles rather distinctly, mostly longitudinaly striate-rugose. Head, mesosoma, petiole and gaster shagreened, with sides of mesosoma more distinctly sculptured, reticulate-punctate. Tips of pronotal and petiolar spines rather smooth, polished.

Mandibular masticatory borders and outer margins apically with several, semierect, golden hairs. Anterior clypeal margin with a few long, anteriorly directed setae medially and fringe of shorter setae laterally. Several pairs of medium length, erect, golden hairs near anterior and basal margins of clypeus, along frontal carinae and a single pair on vertex. Antennal scapes with few, short, erect hairs fringing apex. Pair of downward directed longer hairs on anterior face of fore coxae. Gaster with several medium length hairs on apical segments, with their length distinctly increasing towards gastral apex and over venter. Rather dense, appressed pubescense virtually hiding underlying sculpturation; pubescence distinctly longer and silvery, or white, on sides of mesosoma; shorter, much finer and with somewhat yellowish on dorsum.

Colour: Black throughout.

Sexuals and immature stages unknown.

REMARKS. The holotype is the only known specimen of this species. *Polyrhachis festina* is somewhat similar to *P. foreli*, a species known from Queensland and Papua New Guinea. However, in addition to being distinctly smaller (HL 1.84 in *P. festina* versus 2.21-2.46 in *P. foreli*), *P. festina* lacks a blunt, postocular carina, that in *P. foreli* runs from posterior margin of each eye towards the occipital corner. The dorsal margin of the petiole between the lateral spines in *P. festina* is straight, relatively narrow and only very weakly elevated medially, while in *P. foreli* the dorsal margin is broad and distinctly convex. The accessory petiolar teeth, situated below the bases of the spines, are very short and acute in *P. festina*, while they are distinctly flattened and dorsally emarginate in *P. foreli*.

19. Polyrhachis hastata (Latreille, 1802) (FIG. 3E-F)

Formica hastata Latreille, 1802: 129, pl. 4, fig. 23. ?Holotype worker. Type locality: ?INDONESIA ('Indes Orientales') (Riche), ?MNHN (type presumed lost).

Polyrhachis hastata (Latreille). Fr. Smith, 1858:59.

MATERIAL. SULAWESI TENGAH: nr Morowali, Ranu R. area, 27.i.-20.iv.1980 (M.J.D. Brendell, B.M. 1980-280) (w). SULAWESI TENGGARA: nr Sanggona, Base Camp, Gn Watuwila, c. 200m, 10.-15.x.1989 (Malaise trap) (C.van Achterberg) (w); ditto, 15.-19.x.1989 (Malaise trap) (C.van Achterberg) (w). SULAWESI SELATAN: Balan Ba'na nr Soroako, 02°39'S, 121°12'E, 130m, 21.x.1999 (K. Ogata & K. Masaoka #89) (w); SE of Laduladu, 02°33'S, 121°22'E, 230m, 21.x.1999 (K. Ogata & K. Masaoka #93) (w).

REMARKS. The type of *P. hastata* cannot be found in MNHN or in any other collection examined and must be considered lost. However, I have examined a few available identified specimens lodged in BMNH, HNHM, MCSN, MHNG and NHMW collections that conform well with the original description and illustration of *P. hastata*. These specimens are undoubtedly conspecific with the recent material from Sulawesi.

Polyrhachis hastata is a very distinctive and evidently rare species.

20. Polyrhachis isacantha Emery, 1887 (FIG. 3G-H)

Polyrhachis isacantha Emery, 1887: 232, pl. 4, figs 22, 23. Syntype workers, queen. Type locality: INDONESIA, Goram I. (= Seram I.) (L.M. D'Albertis), MCSN (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, Tumpah R., vi.-4.vii.1985, for. edge (N.E. Stork et al.) (w). SULAWESI TENGAH: nr Morowali, Ranu R. area, 27.i.-20.iv.1980 (M.J.D. Brendell, B.M. 1980-280) (w).

REMARKS. The specimens from Sulawesi are slightly smaller than the syntypes from Seram I. (HL 2.03-2.18 versus 2.21-2.37 in syntypes) but they are essentially identical in all other aspects.

21. Polyrhachis ithona Fr. Smith, 1860

Polyrhachis ithonus Fr. Smith, 1860b: 99, pl. 1, fig. 18. Syntype worker, queen. Type locality: INDONESIA, Batjan I. (A.R. Wallace), OXUM (examined).

Polyrhachis chaonia Fr. Smith, 1861: 42, pl. 1, fig. 18. Holotype queen. Type locality: INDONESIA, Halmahera I. (A.R. Wallace), OXUM (examined). Synonymy by Bolton, 1974:177.

(For full synonymy citations see Bolton (1995: 350); also Kohout (1988: 430-431, figs 1B, 1D)

REMARKS. Emery (1901) listed this species from Sulawesi as *P. chaonia*, however, I have only seen specimens from Morotai (= Morty), Halmahera and Ternate Islands in the Moluccas.

22. Polyrhachis nigropilosa Mayr, 1872

Polyrhachis nigropilosa Mayr, 1872: 141. Syntype workers. Original localities: INDONESIA, SULAWESI (Stevens); BORNEO, Sarawak (J. Doria), NHMW (examined).

(For full synonymy citations see Kohout (1998: 522.)

REMARKS. *Polyrhachis nigropilosa* is a rather common species known from Borneo and Peninsular Malaysia. The syntype worker in the Mayr collection (NHMW) appears to be the only confirmed specimen from Sulawesi.

23. Polyrhachis numeria Fr. Smith, 1861

Polyrhachis numeria Fr. Smith, 1861: 42, pl. 1, fig. 25. Holotype worker. Type locality: SULAWESI (A.R. Wallace), OXUM (examined).

Polyrhachis (Johnia) schizospina Karawajew, 1927: 44. Holotype queen. Type locality: INDONESIA, Princen-Eiland in Sundastrasse (W. Karawajew #2397), IZAS (examined). Synonymy by Kohout, 1988: 527.

(For full synonymy citation see Kohout 1998: 527.)

REMARKS. The unique holotype is apparently the only specimen of *P. numeria* recorded from Sulawesi. The only comparable specimens examined are the workers from Andaman Is (BMNH) and Southern Thailand (QM), and a single queen described by Karawajew as *P. (Johnia) schizospina* (IZAS) (see Kohout, 1988).

24. Polyrhachis olena Fr. Smith, 1861 (FIG. 4A-B)

Polyrhachis olenus Fr. Smith, 1861: 39, pl. 1 fig. 8. Holotype worker. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined).

Polyrhachis eurytus Fr. Smith, 1861: 43, pl. 1, fig. 24. Holotype queen. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined). Synonymy by Bolton, 1974: 177.

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, Gn Ambang F.R., nr Kotamobagu, 1200m, 18.ii.1985, fog. (N.E. Stork et al.) (w); ditto, 31.vii.1985, fog. (N.E. Stork et al.) (w); ditto, Danau Mooat, nr Kotamobagu, 1200m, v.1985 (N.E. Stork et al.) (w); ditto, 1100m, 31.vii.1985, *Pandanus* fog. (N.E. Stork et al.) (w).

REMARKS. Comparison of the Domoga-Bone specimens with the *P. olena* holotype shows them virtually identical and undoubtedly conspecific. This species is most similar to *P. brendelli* and *P. browni*, both described above, with the differences between all three species given in the remarks section of *P. brendelli*.

25. Polyrhachis rixosa Fr. Smith, 1858 (FIG. 4C-D)

Polyrhachis rixosus Fr. Smith, 1858: 68. Holotype queen. Type locality: INDONESIA, SULAWESI, BMNH (examined).

Polyrhachis lycidas Fr. Smith, 1861: 43, pl. 1, fig. 23. Holotype worker. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined). Synonymy by Kohout 1998: 523.

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 1985 (R.H.L. Disney #74) (w, alate ♀); ditto, 400m, 11.ii.1985, fog. (N.E. Stork et al.) (w); ditto, 25.iv.1985 (N.E. Stork et al.) (w, ♂); ditto, 7.vi.1985 (N.E. Stork et al.) (w); ditto, 8.ii.1985, 200-400m, lowland for., fog. (P.M. Hammond) (w); ditto, 19.vii.1985, fog. (N.E. Stork et al.) (w); ditto, Maze Toraut R., 00°34'N, 123°54'E, c. 250m, 16-23.xi.1985 (C.van Achterberg) (w); Mt Klabat, Air Madidi slope, 400-600m, 13-19.vi.1972, wet for. (W.L. Brown) (w); Tanghoko-Duasudara Res., 01°29'N, 125°11'E, 100m, 1.vii.2001, lowland rf. (D.M. Olson) (w). SULAWESI TENGAH: nr Batul, Seseba, c. 375m, 6-9.xi.1989 (Malaise trap) (C.van Achterberg) (w); Lore Lindu NP, nr Dongi-Dongi shelter, 01°15'S, 120°20'E, c. 1100m, 6-9.xii.1989 (Malaise trap) (C.van Achterberg (w). SULAWESI TENGGARA: Silea, 28km W of Kendari, 150m, rf., 12-14.vii.1972 (W.L. Brown) (w). SULAWESI SELATAN: Balampesoang For., 5-8km NE of Tanete, 400m, 8-10.vii.1972, degr. rf. (W.L. Brown) (w).

REMARKS. Kohout (1998) provided characters to distinguish *P. rixosa* from the similar *P. sculpturata* Fr. Smith.

26. Polyrhachis rufofemorata Fr. Smith, 1859

Polyrhachis rufofemoratus Fr. Smith, 1859: 142. Holotype worker. Type locality: INDONESIA, Aru Is (A.R. Wallace), OXUM (examined).

Polyrhachis merops Fr. Smith, 1860b: 98, pl. I, fig. 17. Holotype worker. Type locality: INDONESIA, Batjan I. (A.R. Wallace), OXUM (examined).

(For full synonymy citations see Kohout, 1998: 523).

REMARKS. This species was listed from Sulawesi by Emery (1901; 1925) as "*P. rufofemorata* F. Sm. mit var. *merops* F. Sm.". It is known to occur from the Moluccas to New Guinea and south to Cape York Peninsula in Queensland. I have not seen any specimens originating from Sulawesi.

27. Polyrhachis sculpturata Fr. Smith, 1860 (FIG. 4E-F)

Polyrhachis sculpturata Fr. Smith, 1860a: 70. Syntype worker, queen. Type locality: INDONESIA, SULAWESI, Makassar (A.R. Wallace), OXUM (examined).

Polyrhachis sumatrensis r. *hamulata* Emery, 1887: 234. Syntype workers, queen. Type locality: INDONESIA, SULAWESI, Kandari (O. Beccari), MCSN (examined). Synonymy by Kohout, 1998: 524.

MATERIAL. SULAWESI TENGGARA: nr Sagona, Base Camp, Gn. Watuwila, c. 200m, 10.-15.x.1989 (Malaise trap) (C.van Achterberg) (w); ditto, 15.x.-5.xi.1989 (Malaise trap) (C.van Achterberg) (w); ditto, 225m, 15.x-5.xi.1989 (Malaise trap) (C.van Achterberg) (w); ditto, 12.-15.x.1989 (Malaise trap) (C.van Achterberg) (w). SULAWESI SELATAN: SE of Laduladu, 02°33'S, 121°22'E, 230m, 21.x.1999 (K. Ogata & K. Masaoka #95) (w); Karaentha, 05°02'S, 119°44'E, 270m, 23.x.1999 (K. Ogata & K. Masaoka #98) (w, ♀); Sampulage nr Mangktana, 02°20'S, 120°48'E, 800m, 19.x.1999 (K. Ogata & K. Masaoka #74) (w).

REMARKS. Notes on *P. sculpturata*, including its synonyms and similarity to *P. rixosa* Fr. Smith, were given by Kohout (1998) under the latter species.

28. Polyrhachis striatorugosa Mayr, 1862

Polyrhachis striatorugosus Mayr, 1862: 686, pl. 19, fig. 9. Syntype workers. INDONESIA, JAVA (Sichel), NHMW (examined).

(For full synonymy citations see Kohout, 1998: 524.

REMARKS. This species occurs sporadically throughout Indonesia on Sumatra, Java and several other islands, including Flores. It was listed from Sulawesi by Emery (1901) but I have not seen any specimens originating from the island.

Polyrhachis vestita species-group

KEY TO *VESTITA*-GROUP SPECIES (based on workers)

1. Larger species (HL >3.10); dorsum of petiole acute in lateral view (Fig. 5D, H) 2
   Smaller species (HL <2.75); dorsum of petiole rounded in lateral view(Fig. 4I1) ..... *gobini* sp. nov.
2. Antennal scape with distinct process near apex (Fig. 6B) .....*ogatai* sp. nov.
   Antennal scape without process near apex 3
3. Whole body with rather thick, relatively long hair (Figs 5B, F) 4
   Body with only diluted, relatively short hair (Fig. 5D) ..... *masaokai* sp. nov.
4. Pubescence distinctly rusty-red..... *cognata* sp. nov.
   Pubescence rich golden or pale yellow.... *vestita* Fr. Smith

29. Polyrhachis cognata sp. nov. (FIG. 5A-B)

MATERIAL. HOLOTYPE: SULAWESI TENGGARA, Wolasi, Pangalulu, 04°10'S, 122°30'E, 140m, 13.x.1999, K. Ogata & K. Masaoka (worker). PARATYPE: data as for holotype (worker). Type distribution: Holotype in QM (QMT144147), paratype in MCZC.

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 14.01, 13.91; HL 3.53, 3.48; HW 2.62, 2.57; CI 74, 74; SL 4.64, 4.64; SI 177, 180; PW 2.07, 2.07; MTL 5.44, 5.39 (2 measured).

Anterior clypeal margin arcuate, very shallowly and widely emarginate medially. Clypeus with rather blunt median carina and shallow depressions just behind weakly raised median portion of anterior margin; median carina distinctly higher and more prominent posteriorly. Clypeus in profile straight for most of its length, posteriorly rounding into moderately impressed basal margin, laterally indicated by a flat, thin line. Frontal triangle distinct. Frontal carinae with sharp, high and steeply elevated laminate lobes; central area concave with poorly defined frontal furow. Sides of head in front of eyes converging towards mandibular bases in weakly convex line; behind eyes sides rounding into convex, medially narrowly upturned and weakly emarginate, occipital margin. Eyes convex, in full face view just reaching or marginally breaking lateral cephalic outline. Ocelli lacking. Pronotal dorsum weakly convex, with pair of long, slender, anterolaterally directed, horizontal spines; dorsolateral edges

of spines continuous with parallel-sided pronotal margins. Mesonotal dorsum rather flat, strongly transverse, with laminate, anteriorly upturned lateral margins that are rounded in dorsal view. Propodeum with lateral margins forming anteriorly rounded and upturned laminae; posterior margins weakly converging into upturned posterior angles. Propodeal dorsum rounding into steep declivity in medially uninterrupted curve. Petiole biconvex in profile; dorsum armed medially with a pair of blunt, broad-based teeth; margin between teeth emarginate and somewhat jagged laterally, terminating in weakly upturned denticles. Anterior face of first gastral segment rather flat basally, with anterodorsal margin widely rounding onto dorsum of gaster.

Mandibles distinctly, longitudinaly striate. Head, mesosoma, petiole and gaster generally very finely reticulate-punctate with sculpturation on vertex of head and dorsum of mesosoma organised into fine, longitudinal striae.

Mandibles along outer margins and masticatory borders with numerous, relatively long, erect and semierect, golden hairs. Anterior clypeal margin fringed medially with medium length, anteriorly directed, golden setae, reducing in length laterally. Leading edge of antennal scapes with numerous short, erect, black hairs; a few hairs arising along inferior edge distally. Front and sides of head with medium length, erect, black hairs, those on vertex distinctly longer and more anteriorly directed. Mesosomal dorsum with numerous, long, anteriorly curved, black hairs, those on sides of mesosoma distinctly shorter. Coxae with several long, black and rusty-brown hairs. Legs with abundant, black and rusty-brown hairs, notably on tibiae, basal segments of tarsi and ventral surfaces of femora. Dorsal surfaces of fore femora hairless; middle and hind femora with only a few, short hairs along dorsal surfaces distally. Petiole with several short, black hairs fringing dorsal margin. Gaster with abundant, relatively long, somewhat posteriorly directed, black and brown hairs. Very short, dense, appressed, rusty-red pubescence over most body surfaces, notably over anterior portion of pronotal dorsum and meso- and metapleurae; somewhat longer, more erect, yellowish pubescence on pronotal collar.

Colour: Black, with legs dark reddish-brown.

Sexuals and immature stages unknown.

REMARKS. *P. cognata* is relatively similar to the other species of the *vestita*-group, notably to *P. ogatai* with which it shares the characteristic rusty red and black pilosity and pubescence. It differs by its smaller size and by lacking the peculiar antennal process found in the unique holotype of *P. ogatai* holotype (Fig. 6B).

30. **Polyrhachis gobini** sp. nov. (FIG. 4G-H)

MATERIAL. HOLOTYPE: SULAWESI SELATAN, Cagar Alam Karaenta, Kabupaten Maros, c. 05°00'S, 119°45'E, c. 265-315m, iii.1996, secondary rf. on limestone karst hills, B. Gobin (worker). PARATYPES: data as for holotype (10 workers, 1 dealate queen). Type deposition: Holotype (QMT144148), 1 paratype worker and paratype queen in QM; 1 paratype worker each in AMNH, ANIC, BMNH, CASC, MCZC and NMNH; 3 paratype workers in KULB (B. Gobin private collection).

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 10.03, 9.07-10.78; HL 2.50, 2.32-2.72; HW 1.59, 1.51-1.71; CI 64, 63-65; SL 3.15, 2.87-3.33; SI 198, 190-198; PW 1.03, 0.91-1.11; MTL 3.21, 2.82-3.43 (12 measured).

Anterior clypeal margin arcuate, entire. Clypeus in profile weakly sinuate with median carina, that is low and blunt anteriorly, more distinctly elevated posteriorly; clypeus rounding into moderately impressed basal margin that is well defined laterally. Frontal triangle weakly impressed. Frontal carinae sinuate, with highly raised, laminate margins; central area concave, very narrow anteriorly, flat and wider posteriorly; frontal furrow indistinct. Head widest just in front of eyes with sides weakly convex and converging anteriorly towards mandibular bases; behind eyes sides converging in weakly convex line into a very narrow occipital margin. Eyes convex, almost protuberant, situated well forward from occipital corners; in full face view clearly breaking lateral cephalic outline. Ocelli lacking, relative position of median ocellus indicated by distinct puncture. Pronotal dorsum with pair of relatively short, acute, anteriorly directed, horizontal spines; their lateral edges continued for a short distance and merging with rather blunt, parallel, pronotal margins that run to about mid length; posterior half of pronotal dorsum immarginate. Mesonotal dorsum transverse, with distinct lateral margins anteriorly, rounding onto sides posteriorly. Propodeal dorsum convex in profile with lateral margins narrowly rounded anteriorly, poorly defined posteriorly and terminating in more-or-less distinct denticles or tubercules; propodeal dorsum rounding into declivity in medially uninterrupted, oblique curve. Petiole biconvex, only marginally higher than width at base, with virtually hexagonal outline

in frontal view; dorsal margin blunt, rather flat medially, angular laterally and descending towards blunt lateral angles. Anterior face of first gastral segment low, distinctly lower than height of petiole; rather flat at base and rounding onto dorsum of segment.

Mandibles at masticatory borders smooth and polished; finely, longitudinally striate towards bases. Head reticulate-punctate with sculpturation distinctly increasing in intensity to rugose along sides and somewhat rugose-striate between eyes and frontal carinae. Dorsum of mesosoma and gaster finely shagreened, weakly polished, with sides of mesosoma more-or-less reticulate-punctate.

Mandibles along outer margins and masticatory borders with numerous, curved, golden hairs and with closely appressed hairs towards bases; several longer, erect hairs arising from outer margins near bases. Anterior clypeal margin with a few long, anteriorly directed golden setae medially and several short setae fringing margin laterally. Head with abundant, medium length to long, erect and somewhat anteriorly directed, mostly yellow hairs. Antennal scapes with shorter, erect hairs, most numerous along leading edge, and with fringe of hairs at apex. Mesosomal dorsum and petiole with numerous erect, semierect and variously curved, medium length, yellow and light yellowish-brown hairs, with those on sides somewhat shorter and less abundant. Legs with numerous, medium length, erect hairs on most surfaces, except dorsa of middle and hind femora where they are rather diluted; hairs completely absent from dorsa of front femora. Gaster with relatively long, erect, somewhat posteriorly curved, yellow or yellowish-brown hairs, most abundant and more golden around apex. Relatively long, closely appressed, mostly golden pubescence in various densities over most body surfaces, somewhat diluted near occipital corners, pronotal dorsum between spines and laterally on first gastral segment.

Colour: Black, with only tips of mandibular teeth reddish-brown; extreme tip of apical funicular segments yellowish-brown. Legs distinctly light orange or yellowish-red, with distal ends of femora and proximal ends of tibiae shade darker; tarsi black.

Queen. Dimensions: TL c. 11.14; HL 2.72; HW 1.79; CI 66; SL 3.17; SI 177; PW 1.66; MTL 3.17 (1 measured).

Queen slightly larger than worker with usual characters identifying full sexuality, including three ocelli, complete thoracic structure and wings. Pronotum with pair of short, broad-based, anteriorly and weakly downward directed spines. Mesoscutum almost as long as wide; lateral margins strongly converging anteriorly into rather narowly rounded anterior margin; median line distinct; parapsides flat, only weakly raised posteriorly; mesoscutum in profile with relatively low, widely rounded anterior face and flat dorsum. Mesoscutellum very weakly convex and only marginally elevated above dorsal plane of mesosoma; metanotal groove distinct. Propodeum convex in outline with sides terminating posteriorly into very short, medially directed ridges; propodeal dorsum descending into oblique declivity in medially uninterrupted line. Sculpturation of body, pilosity, pubescence and colour virtually as in worker.

Male unknown; immature stages (larvae and pupae) in KULB (B. Gobin private collection).

REMARKS. *P. gobini* is a very distinct member of the *vestita* species-group. Altough it shares several characters with the other species of the group, it does not seem closely related to any species in particular. The rather narrow and elongated mesosomal dorsum somewhat resembles that of *P. philippinensis* Fr. Smith, but their other characters differ widely. The pronotal spines in *P. philippinensis* are relatively long and project anterolaterally, while in *P. gobini* they are rather short and project anteriorly. Moreover, the petiole in *P. philippinensis* is slender, with its dorsolateral edge armed with a pair of spines, while in *P.gobini* the petiolar dorsum is entire and unarmed.

Polyrhachis gobini appears endemic to Sulawesi with its known distribution limited to the type locality. The following information on the species nesting habits are an extract from the field observations made by the collector Bruno Gobin: "[...] I was especially interested in the *Diacamma* sp. and kept confusing them with the foragers of *Polyrhachis* sp. Nest sites and foraging workers really looked alike. It [*Polyrhachis gobini*] is an arboreal ant nesting in cavities in trees. They more-or-less seal the

nest entrance with detritus and pulp of rotten wood which they seem to excavate. They appear to forage singly. I sampled 2 nests in which there were larvae and cocoons, but no queen(s), suggesting they are polydomous. [Later] I found a founding queen with two workers in a small cavity without nest material [...] I tried to raise the nest but the queen died." (B. Gobin, *pers. comm.*).

31. Polyrhachis masaokai sp. nov. (FIG. 5C-D)

MATERIAL. HOLOTYPE: SULAWESI SELATAN, Sampulage nr Mangktana, 02°16'S, 120°47'E, 1000m, 19.x.1999, K. Ogata & K. Masaoka (worker). PARATYPE: data as for holotype (worker). Type distribution: Holotype in QM (QMT144149), paratype in MCZC.

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 12.50, 12.80; HL 3.12, 3.12; HW 2.34, 2.32; CI 75, 74; SL 4.23, 4.23; SI 181, 182; PW 2.02, 2.07; MTL 4.74, 4.63 (2 measured).

Anterior clypeal margin arcuate, very shallowly and obtusely truncate medially. Clypeus with distinctly raised median carina; clypeus in profile straight for most of its length, narrowly rounding into weakly impressed basal margin, indicated laterally by a very thin line breaking culpturation. Frontal triangle weakly impressed. Frontal carinae with sharp, highly and steeply elevated laminate lobes; central area deeply concave with weakly impressed frontal furrow. Sides of head in front of eyes converging towards mandibular bases in very weakly convex line; behind eyes sides rounding into convex, medially strongly narrowed and posteriorly weakly emarginate, occipital margin. Eyes convex, in full face view marginally exceeding lateral cephalic outline. Ocelli lacking, relative positions poorly indicated by shallow punctures. Pronotal dorsum weakly convex in profile, with pair of long, slender, anterolaterally directed, horizontal spines; their dorsolateral edges continuous with weakly laminate lateral margins of pronotum. Mesonotal dorsum strongly transverse, with laminate, weakly upturned, posteriorly converging lateral margins. Propodeum with lateral margins weakly laminate, narowly rounded and upturned anteriorly, posteriorly produced into distinct, strongly upturned teeth; propodeal dorsum descending into oblique declivity in medially uninterrupted line. Petiole in profile with anterior and posterior faces convex at base, strongly converging dorsally; dorsum margin medially with a pair of blunt, broad-based teeth and additional blunt denticles laterally before terminating in rather distinct, strongly upturned, dorso-laterally directed teeth. First gastral segment flat at base with anterior face widely rounding onto dorsum.

Mandibles distinctly and regularly, longitudinally striate. Head, mesosoma, petiole and gaster mostly shagreened, with sculpturation on vertex and sides of head distinctly more intense, somewhat reticulate; sides of mesosoma and base of petiole reticulate, finely wrinkled dorsally.

Mandibles with several, curved hairs near masticatory bordes and along outer margins; several appressed hairs arising from pits towards bases. Anterior clypeal margin with several relatively long, anteriorly directed, golden setae and a few shorter setae fringing margin laterally. Clypeus, front and sides of head and mesosoma with numerous, short to medium length, erect, hairs. Vertex of head and dorsum of mesosoma with abundant, distinctly longer, erect and somewhat curved, mostly anteriorly directed hairs. A few, very short, erect hairs on leading edge of antennal scapes; one or two hairs arising from inferior edge distally. Fore coxae and legs, excluding dorsal surfaces of femora, with medium length, erect, mostly golden hairs. Petiole with several shorter hairs near dorsal margin. Gaster with patch of posteriorly curved, rather long hairs at anterodorsal margin and shorter, erect hairs lining posterior margins of dorsal and ventral surfaces of apical segments. A very few, short erect hairs arising from dorsum of first gastral segment. Short, silvery white or greyish, closely appressed, rather dense pubescence on most body surfaces.

Colour. Black throughout, with only mandibular masticatory borders diffusely dark reddish-brown.

Sexuals and immature stages unknown.

REMARKS. Like other members of the *vestita*-group, *P. masaokai* has a scale-like petiole with its dorsal margin arcuate, more-or-less entire or only weakly and obtusely dentate or jagged. *Polyrhachis. masaokai* differs from all the other known species of the group in having the dense body pubescence silvery white, while in *P. cognata* and *P. ogatai* the pubescence is distinctly rusty red and in *P. vestita* rich golden or yellow. It also differs from *P. ogatai* in lacking the peculiar process near apex of the antennal scapes found in that species. *Polyrhachis masaokai* differs from *P. vestita* by the shape of dorsal petiolar margin

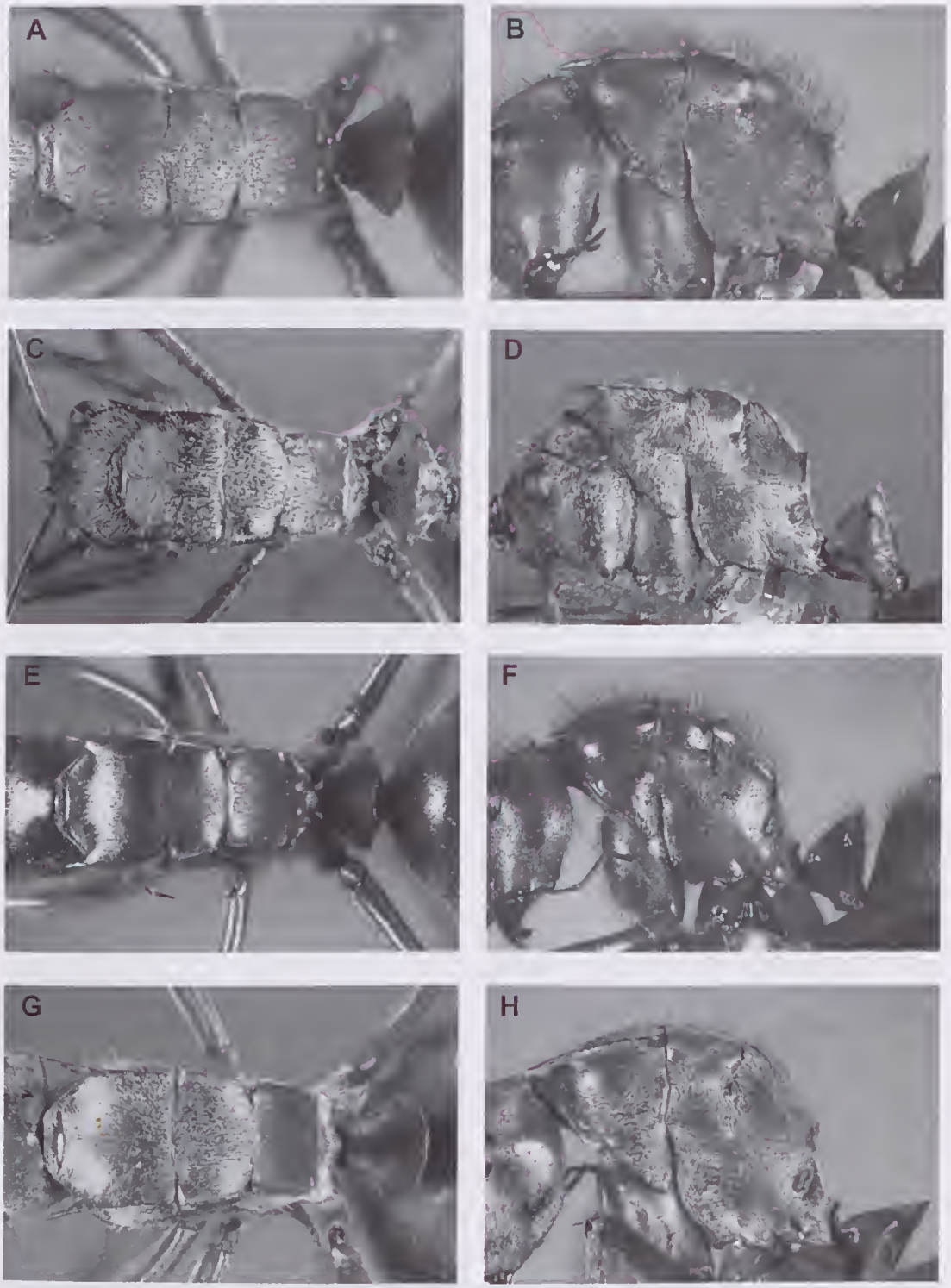

FIG. 5. *Polyrhachis* (*Myrma*) species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. cognata* sp. nov.; C-D, *P. masaokai* sp. nov.; E-F, *P. ogatai* sp. nov.; G-H, *P. vestita* Fr. Smith (not to scale).

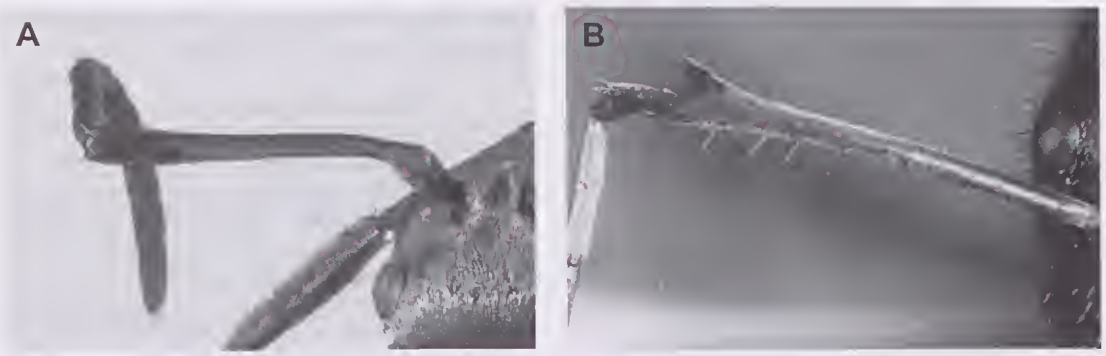

FIG. 6. *Polyrhachis* (*Myrma*) species, Antennal scapes. A, *P. bosi* sp. nov., dorsal view; B – *P. ogatai* sp. nov., frontal view (not to scale).

that, in *P. vestita* is virtually entire, while it is dentate with distinct lateral teeth in *P. masaokai*.

32. Polyrhachis ogatai sp. nov. (FIGS 5E-F, 6B)

MATERIAL. HOLOTYPE: SULAWESI SELATAN, Kayulagi nr Mangktana, 02°23'S, 120°47'E, 600m, 20.x.1999, K. Ogata & K. Masaoka (worker). Type distribution: unique holotype in QM (QMT144150).

DESCRIPTION. *Worker*. Dimensions of holotype: TL e. 15.12; HL 3.63; HW 2.77; CI 76; SL 4.69; SI 169; PW 2.47; MTL 5.64.

Anterior clypeal margin arcuate, with two shallow notches medially. Clypeus in profile sinuate, shallowly concave anteriorly, with short, distinct carina before posteriorly rounding into well impressed basal margin, laterally indicated by a thin line breaking sculpturation. Frontal triangle indistinct. Frontal carinae with anteriorly sinuate, highly and steeply raised laminate lobes; rather flat posteriorly; central area concave with short frontal furrow. Antennal scapes distinctly broadened apically, somewhat dorso-ventrally compressed and shallowly excavated on ventral aspect, with dorsally projecting, blunt process (Fig. 6B) near their apices. Sides of head in front of eyes only weakly convex, converging towards mandibular bases; behind eyes sides rounding into convex, strongly narrowed and medially emarginate, occipital margin. Eyes convex, in full face view not reaching lateral cephalic outline. Ocelli lacking. Pronotal dorsum with pair of relatively short, anteriorly directed spines; lateral edges of spines continuous with weakly posteriorly converging pronotal margins. Mesonotum wider than long with lateral margins converging posteriorly. Propodeal dorsum only marginally wider than long with lateral margins parallel, terminating posteriorly in short, weakly raised ridges; margins of ridges continued inwards and slightly downwards for a short distance; propodeal dorsum descending into declivity in only weakly curved, medially uninterrupted line. Petiole with anterior and posterior faces virtually flat in profile, strongly converging dorsally; dorsal petiolar margin shallowly emarginate medially, somewhat jagged laterally and terminating in short denticles. Anterior face of first gastral segment very high, distinctly higher than petiole, broadly rounding onto dorsum.

Mandibles rather polished with fine, longitudinal striae. Clypeus, front and sides of head rather distinctly reticulate-punctate, with reticulae on clypeus somewhat antero-medially converging. Vertex, dorsum of mesosoma, petiole and gaster more finely reticulate-punctate with weak satin gloss.

Mandibles along outer margin and near masticatory borders with several golden hairs with a distinct rusty-red tint. A few, relatively long setae of same colour arising medially from anterior clypeal margin with shorter setae fringing margin laterally. Numerous, semierect and erect, mostly black or dark brown, medium length hairs on clypeus, sides of head and along frontal carinae. Distinctly longer, longest almost as long as the greatest diameter of eye, somewhat anteriorly curved, black or rusty-brown hairs, rather abundant on vertex and mesosomal dorsum; shorter, dorsally curved, dark brown or rusty-brown hairs on sides of mesosoma. Front coxae and legs, except dorsal surfaces of femora, with numerous black and brown hairs. Middle and hind femora towards distal ends with some shorter, erect hairs dorsally. Petiole with numerous, mostly black, shorter hairs. Gaster dorsally and ventrally with black and brown, relatively long, posteriorly directed, hairs. Closely

appressed, rusty brown pubescence on most body surfaces, except mandibles, clypeus, front and sides of head; pubescence most dense and distinctly longer on mesosoma and extremely short, with very distinct rusty-red tint on vertex, petiole and gaster.

Colour: Black throughout; only apical mandibular teeth and extreme tip of apical funicular segments reddish- or yellowish-brown.

Sexuals and immature stages unknown.

REMARKS. *Polyrhachis ogatai* is easily recognised among members of the *vestita*-group by its large size and the peculiar process at the apex of antennal scape.

33. Polyrhachis vestita Fr. Smith, 1860 (FIG. 5G-H)

Polyrhachis vestitus Fr. Smith, 1860a: 71. Holotype worker. Type locality: INDONESIA, SULAWESI, Makassar (A.R. Wallace), OXUM (examined).

Polyrhachis vestita var. *unicolor* Emery, 1898: 242. Syntype workers. Type locality: INDONESIA, SULAWESI (H. Fruhstorfer), MCSN (examined). Synonymy by Kohout, 1998: 525.

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 1985 (R.H.L. Disney #44) (w); ditto, 400m, 11.ii.1985, fog. (N.E. Stork et al.) (w); ditto, 6.-13.ii.1985 (N.E. Stork et al.) (w); ditto, 7.vi.1985 (N.E. Stork et al.) (w); ditto, 230m, 10.iii.1985, fog. (N.E. Stork et al.) (w); ditto, 400m, 19.vii.1985, fog. (N.E. Stork et al.) (w); ditto, Gn. Mogogonipa, 22-25.viii.1985 (J. Huijbregts RMNH/HH 430) (w). SULAWESI TENGAH: Mt Tambusisi, 01°38'S, 121°23'E, 6500', 8.-9.iv.1980 (M.J.D. Brendell, B.M. 1980-280) (w); Lore Lindu NP, nr Dongi-Dongi shelter, 01°15'S, 120°20'E, c. 1000m, 4-9.xii.1985 (Malaise trap) (C.van Achterberg) (w); ditto, c. 1100m, 6.-9.xii.1985 (Malaise trap) (C.van Achterberg) (w); ditto, c. 975m, 6.xii.1985 (C.van Achterberg) (w); ditto, Toro, Bulu Lonca, 1130m, 27&29. iv.2005, nat. for., fog. (M.M. Bos #4) (w); ditto, Toro, Gn. Kalabul, 950m, 5.v.2005, nat. for., fog. (M.M. Bos #4) (w); ditto, Toro, Kole Wuri, 1010m, 27.iv.2005, nat. for., fog. (M.M. Bos #4) (w). SULAWESI SELATAN: nr Bantimurung Karaente N.R., 250-300m, 18.iv.1991 (C.van Achterberg) (w); Cagar Alam Karaenta, Kabupaten Maros, 265-315m, iii.1996 (B. Gobin) (w); Balampesoang For., 5-8km NE of Tanete, 400m, degr. rf., 8-10.vii.1972 (W.L. Brown) (w); Bengonbengo nr Camba, 05°01'S, 119°46'E, 520m, 8.x.1999 (K. Ogata & K. Masaoka) (w).

REMARKS. *Polyrhachis vestita* was discussed in detail by Kohout (1998: 525).

Polyrhachis zopyra species-group

34. Polyrhachis zopyra Fr. Smith, 1861

Polyrhachis zopyrus Fr. Smith, 1861: 43, pl. 1, fig. 22. Holotype worker. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 9.-16.v.1985 (N.E. Stork et al.) (w, ♀); ditto, 00°34'N, 123°54'E, c. 220m, 9.-19.xi.1985 (Malaise trap) (C.van Achterberg) (w); ditto, Tumpah R., 11.-19. xi.1985 (Malaise trap) (C.van Achterberg) (w); ditto, Maze Toraut R., 16.-23.xi.1985 (Malaise trap) (C.van Achterberg) (w); ditto, Tumpah R., 19.-23.xi.1985 (Malaise trap) (C.van Achterberg) (w); ditto, Base camp, 200m, 13.x.1985, pitfall trap (Bosmans & Van Stalle #024) (w); ditto, Tumpah R., 7.x.1985 (Bosmans & Van Stalle #004) (w); subcamp Barney's, 300m, 7.xi1985 sweeping (Bosmans & Van Stalle #085) (♀). SULAWESI TENGAH: nr Morowali, Ranu R. area, 27.i.-20.iv.1980 (M.J.D. Brendell B.M.1980-280) (w); Kebung Kopi nr Palu (Sk. Yamane) (w). SULAWESI TENGGARA: Lanowulu, Rowa Apa Watumohae NP, 04°28'S, 122°08'E, 40m, 12.x.1999 (K. Ogata & K. Masaoka #34. SULAWESI: Latimodjong Mts (Clagg) (w).

REMARKS. *Polyrhachis zopyra* is the only member of the *zopyra* species-group endemic to Sulawesi. It is very similar to *P. edentula* described by Emery from Sumatra, and can be distinguished by the characters listed under that species (see under Nomenclatural changes to extralimital fauna).

Subgenus Myrmatopa Forel, 1915

The subgenus *Myrmatopa* was divided by Emery (1925) into two species-groups (the *wallacei*- and *schang*-groups) and this arrangement was followed by Dorow (1995). However, I am further subdividing the *wallacei*-group and placing several of its constituent species into a new *flavicornis*-group. This group is characterised by the mesosomal dorsum being distinctly marginate along its entire length and by the black colour of the body (thus closely resembling some species of the subgenus *Campomyrma*). In contrast, the mesosoma of the redefined *wallacei*-group, is distinctly marginate only along the mesonotal and propodeal dorsa. The pronotal margins are completely lacking or evident only at the anterior pronotal angles and the colour of the body is yellowish- or light reddish-brown. The species of the *schang* species-group differ from members of the other two groups in having the lateral margins

of the mesonotum distinctly raised dorsally (Fig. 11B) and a completely immarginate pronotal dorsum.

Polyrhachis flavicornis species-group

KEY TO *FLAVICORNIS*-GROUP SPECIES
(based on workers)

1. Dorsal body surfaces, including appendages, with numerous, relatively long, erect hairs (Fig. 7A-B) . . . *.chaita* sp. nov.
   Dorsal body surfaces without erect hairs 2
2. Larger species (HL >1.53) 3
   Smaller species (HL <1.50) 4
3. Propodeal dorsum strongly transverse, more than twice as wide as long; petiolar dorsum with distinct pair of acute intercalary spines (Fig. 7G, H) . . . *.sulawesiensis* sp. nov.
   Propodeal dorsum only weakly transverse, only marginally wider than long; petiolar dorsum without intercalary teeth or spines (Fig. 7E, F) . . . . . *neglecta* sp. nov.
4. Petiolar dorsum with pair of slender, strongly diverging, lateral spines and pair of short, acute, intercalary spines or teeth (Fig. 7C, D) . . . . . *hilaris* sp. nov.
   Petiolar dorsum with pair of rather thick, weakly diverging lateral spines; intercalary teeth lacking, or only feebly indicated in some specimens. . . . . *.fruhstorferi* Emery

35. Polyrhachis chaita sp. nov.
(FIG. 7A-B)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Dumoga-Bone NP, 400m, 11.ii.1985, fog., N.E. Stork et al. (worker). PARATYPES: data as for holotype (13 workers, 1 alate queen). Type deposition: Holotype, 5 paratype workers and paratype queen in BMNH; 2 paratype workers in ANIC, CASC, MCZC and QM. ADDITIONAL MATERIAL. SULAWESI TENGAH: Lore Lindu NP, Toro, Gn. Kalabui, 950m, 16.& 20.iv.& 5.v.2005, nat. for., fog. (M.M. Bos #10, 12) (w, ♀); ditto, Toro, Gn. Kamonua, 1080m, 20.iv.2005, nat. for., fog. (M.M. Bos #10) (w); ditto, Toro, Bulu Lonca, 1130m, 29.iv.2005, nat. for., fog. (M.M. Boss #10) (w); ditto, Toro, Kole Wuri, 1010m, 27.iv.2005, nat. for., fog. (M.M. Bos #10) (w).

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 6.00, 5.74-6.35; HL 1.56, 1.50-1.59; HW 1.22, 1.12-1.25; CI 78, 75-81; SL 1.87, 1.78-1.93; SI 153, 151-159; PW 1.09, 0.90-1.09; MTL 1.72, 1.65-1.72 (14 measured).

Anterior clypeal margin medially with shallow, truncate flange, laterally flanked by acute denticles. Clypeus in profile very weakly convex, rounding posteriorly into moderately impressed basal margin, laterally basal margin partly concealed by coarse sculpturation. Frontal triangle distinct. Frontal carinae sinuate with margins moderately raised; central area concave with poorly indicated frontal furrow. Sides of head in front of eyes straight, anteriorly converging; behind eyes sides rounding into convex occipital margin. Eyes convex, in full face view clearly breaking lateral cephalic outline. Ocelli lacking. Lateral margins of pronotal dorsum widely rounded with humeri bluntly angular; mesonotal dorsum with lateral margins converging posteriorly, weakly raised towards rounded posterior angles. Propodeal dorsum transverse, lateral margins terminating posteriorly in somewhat flattened, dorsally rounded ridges, appearing in profile as acute teeth; inner margins of teeth continued medially only for a short distance, so that propodeal dorsum descends into declivity in medially uninterrupted curve. Petiolar dorsum armed with two, strong, acute spines, arising dorsolaterally from their bases and widely curving at mid length with their tips directed posterodorsally. Anterior face of first gastral segment flat at base, widely rounding onto dorsum.

Mandibles rather smooth, with very weakly, mostly longitudinal striae basally and numerous piliferous pits. Head, mesosoma and gaster very coarsely reticulate-rugose, reticulae on pronotal dorsum somewhat longitudinally oriented. Antennal scapes and petiolar spines with shallow rugae and piliferous pits. Fore coxae finely and shallowly reticulate. Gaster shagreened with numerous piliferous pits.

Very hairy. Mandibular masticatory borders with several curved hairs; outer mandibular margin fringed with numerous, short, erect hairs. Anterior clypeal margin with one long seta medially and few short setae fringing margin laterally. Whole body covered with whitish and/or pale yellow, short to medium length, erect and variously curved hairs; shorter hairs on antennal scapes and dorsal surfaces of femora. Mostly white, decumbent or semierect, scarce pubescence over most dorsal surfaces, dense and more appressed on gaster.

Colour. Black. Mandibles reddish-brown at bases, distinctly lighter towards masticatory borders. Antennal scapes and basal funicular segments dark reddish-brown, with subsequent segments lightening towards apices; condylae, base of antennal scapes and apical funicular segments distinctly light yellow. Coxae black; femora and proximal ends of tibiae very dark reddish-brown with tibiae a shade lighter distally; tarsi light reddish-brown. Gaster dorsally very dark,

reddish-brown; sides with somewhat diffuse reddish tint.

Queen. Dimensions: TL c. 7.41; HL 1.72; HW 1.28; CI 74; SL 2.12; SI 166; PW 1.18; MTL 1.68 (1 measured).

Queen very similar to worker, with characters identifying full sexuality, including three ocelli, complete thoracic structure and wings. Pronotal shoulders widely rounded. Mesoscutum only marginally wider than long with lateral margins converging anteriorly, forming moderately rounded anterior margin; median line distinct; parapsides weakly raised posteriorly; anterior face of mesoscutum relatively low in profile; dorsum only weakly convex anteriorly, flat posteriorly. Mesoscutellum only marginally raised above dorsal plane of mesosoma, convex and strongly rounding into distinctly impressed metanotal groove. Propodeal dorsum convex in profile with lateral margins terminating posteriorly in upturned ridges identical to those in worker. Petiolar spines similar to those in worker, slightly shorter. Sculpturation, pilosity and colour scheme virtually as in worker.

Male and immature stages unknown.

REMARKS. *Polyrhachis chaita* is somewhat similar to *P. elii*, described by Emery (1900) from Mantawei I. They both have a distinct cover of whitish- or yellowish-grey, mostly short to medium length, erect hairs. However, *P. chaita* differs markedly by its distinctly smaller size (HL 1.50-1.59 in *P. chaita* versus HL 1.84-1.90 in *P. elii*), bluntly angular humeri and distinctly longer, widely diverging and somewhat curved petiolar spines. In contrast, the pronotal humeri in *P. elii* are armed with short, but distinct teeth and the petiolar spines are rather short, stubby and only weakly curved inwards. The sculpturation in *P. chaita* is coarsely rugose and rather irregular, while in *P. elii* the reticulate-rugose sculpturation is finer and somewhat longitudinally directed, notably on the pronotal dorsum.

Specimens from Lore Lindu NP differ from the type series specimens from Dumoga-Bone in having the petiolar spines more steeply raised, only weakly divergent and curved inwards. Also, the pronotal humeri are distinctly rounded without any indication of humeral angles, while they are bluntly angular in the Dumoga-Bone specimens. However, all the workers are very similar in all other aspects and, since the queens are virtually identical, I consider that they represent different populations of a single biological species.

36. **Polyrhachis fruhstorferi** Emery, 1898

Polyrhachis fruhstorferi Emery, 1898: 238. Syntype workers. Type locality: INDONESIA, SULAWESI, Toli-Toli (H. Fruhstorfer), MCSN (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP,200-400m, lowland for., 8.ii.1985, fog. (P.M. Hammond) (w); ditto, 400m, 11.ii.1985, fog. (N.E. Stork et al.) (w); ditto, nr Danau Mooat, 1100m, 1.viii.1985, coffee fog. (N.E. Stork et al.) (w); ditto, 400m, 19.vii.1985, fog. (N.E. Stork) (w); ditto, c. 220m, nr Base Camp Torau R., 00°34'N, 123°54'E, 16.v.1985, at light (C.van Achterberg) (♀). SULAWESI TENGAH: Palolo Valley, Nopu (N6), 27.vi.2001 (J. Ketterl #Ants sp. 4) (♀); Lore Lindu NP, Toro, Gn. Kamonua, 1080m, 20.iv.& 5.v.2005, nat. for. fog. (M.M. Bos #5a, 7) (w, ♀); dito, Toro, Gn. Kauboga, 840m, 4.v.2005, cacao agrof., fog (M.M. Bos #5a) (♀); ditto, Kole Wuri, 1010m, 16.iv.2005, nat. for., fog. (M.M. Bos #7, 15) (w); ditto, Toro, Foot of Bulu Lonca, 830m, 30.iv.2005, cacao agrof., fog. (M.M. Bos #7) (w); ditto, Toro, Kaha, 920m, 15.iv.2005, cacao agrof., fog. (M.M. Bos #5a) (♀); ditto, Toro, W foot of Gn. Kalabui, 825m, 30.iv.2005, cacao agrof., fog. (M.M. Bos #11) (w); ditto, Toro, Bulu (Dusun Dua), 21.iv.2005, cacao agrof., fog. (M.M. Bos #11) (w).

REMARKS. I have examined and directly compared two syntype workers of *P. fruhstorferi* (MCSN Emery coll.) with the more recently collected material and found all specimens very similar and undoubtedly conspecific. *Polyrhachis fruhstorferi* bears a close resemblance to *P. flavicornis*, a species described by Fr. Smith (1857) from Singapore and widely distributed throughout South East Asia, including Borneo. In contrast, *P. fruhstorferi* appears to be endemic to Sulawesi. The outline and sculpturation of the head and mesosoma is very similar in both species and they have an almost identical configuration of the petiolar spines. I believe that *P. fruhstorferi* could prove to be just a population of *P. flavicornis*, but a more detailed study of the geographic variation of the latter species will be necessary to ascertain their true relationship. *Polyrhachis fruhstorferi* is also closely related to a newly described *P. neglecta*, with the main differences listed in remarks section under that species.

37. **Polyrhachis hilaris** sp. nov.
(FIG. 7C-D)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Dumoga-Bone NP, nr Danau Mooat, 1100m, 1.viii.1985, coffee fog., N.E. Stork et al. (worker).

PARATYPES: data as for holotype (8 workers); ditto, 230m, 5.ii.1985, fog., N.E. Stork et al. (worker); ditto, 230m, 11.vii.1985, fog., N.E. Stork et al. (3 workers); ditto, 230m, 2.xii.1985, fog., N.E. Stork et al. (2 workers). Type distribution: Holotype and (5) paratypes in BMNH; 2 paratypes each in ANIC, CASC, MCZC and QM.

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 5.00, 4.38-5.19; HL 1.31, 1.15-1.37; HW 1.06, 0.90-1.06; CI 81, 78-84; SL 1.56, 1.40-1.65; SI 147, 144-159; PW 0.87, 0.65-0.87 MTL 1.37, 1.28-1.47 (17 measured).

Anterior clypeal margin medially with shallow, truncate flange, laterally flanked by blunt denticles. Clypeus with poorly defined, blunt median carina; in profile clypeus weakly convex with shallowly impressed basal margin. Frontal triangle distinct. Frontal carinae sinuate with weakly raised margins; central area weakly concave; frontal furrow indistinct. Sides of head in front of eyes straight, rather strongly converging towards mandibular bases; behind eyes sides rounding into evenly convex occipital margin. Eyes convex, in full face view clearly breaking lateral cephalic outline. Ocelli lacking. Pronotal humeri angular, shallowly emarginate behind agles and widely rounded posteriorly; greatest width of pronotal dorsum at mid-length of segment. Mesonotum with lateral margins very weakly raised, converging posteriorly. Propodeal dorsum transverse, with lateral margins terminating posteriorly in dorsally rounded ridges, appearing in profile as acute teeth; ridges continued medially for a short distance with propodeal dorsum between them descending into declivity in medially uninterrupted curve. Petiole armed with pair of relatively long, widely diverging, acute spines; dorsal margin between spines with pair of distinct, acute, intercalary teeth. Anterior face of first gastral segment flat at base, widely rounding onto dorsum.

Mandibles very finely longitudinally striate near bases, rather smooth at masticatory borders with numerous piliferous pits. Head, mesosoma and petiole rather coarsely reticulate-punctate with reticulae on pronotum somewhat irregularly, mostly longitudinally, directed. Antennae finely, legs and gaster more distinctly and closely reticulate-punctate.

Mandibles with several curved, short hairs at outer margins near masticatory borders. Anterior clypeal margin with one long, seta medially and several short setae fringing margin laterally. A few paired, short and medium length, erect, yellow hairs near anterior and basal clypeal margins, along frontal carinae and a single pair of anteriorly curved hairs on vertex. Anterior face of fore coxae with pair of long, erect hairs. Gaster with rather short, golden hairs lining posterior margins of dorsal apical segments; ventral gastral surface with several erect, distinctly longer hairs and numerous, posteriorly curved, shorter hairs. Appressed, white, rather diluted pubescence on dorsum of gaster, virtually absent from other body surfaces.

Colour. Black. Mandibles very dark reddish-brown at their bases, distinctly lighter apically with teeth dark brown. Antennal scapes and basal funicular segments dark reddish-brown, with subsequent segments gradually lightening; condylae, base of antennal scapes and apical funicular segments distinctly light, yellow. Legs distinctly bi-coloured with coxae and femora black, tibiae and tarsi yellow; first tarsal segment shade darker. Gaster dorsally very dark, reddish-brown; sides a shade lighter with somewhat reddish tint.

Sexuals and immature stages unknown.

REMARKS. *Polyrhachis hilaris* is relatively close to *P. fruhstorferi* from Sulawesi and *P. flavicornis* from South East Asia. It differs from both in the form of the petiole which has more slender and widely diverging lateral petiolar spines and a pair of short, acute dorsal, intercalary teeth that are absent in the other species.

38. Polyrhachis neglecta sp. nov.
(FIG. 7E-F)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Dumoga-Bone NP, 230m, 10.iii.1985, fog., N.E. Stork et al. (worker). PARATYPE: data as for holotype, 30.ix.1985, fog., (N.E. Stork et al.) (worker). Holotype in BMNH, paratype in QM. ADDITIONAL MATERIAL. INDONESIA, JAVA, Semarang (no further data) (w); Bogor, 4-8.xi.1985 (Sk. Yamane) (w).

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 6.90, 5.90; HL 1.72, 1.53; HW 1.40, 1.25; CI 81, 82; SL 1.87, 1.72; SI 133, 138; PW 1.18, 1.00; MTL 2.00, 1.72 (2 measured).

Anterior clypeal margin widely truncate medially; truncate portion weakly notched in middle and flanked by distinct denticles. Clypeus with blunt median carina, more distinct posteriorly; clypeus convex in profile but rather flat in middle, posteriorly rounding into moderately impressed basal margin; laterally basal margin forms a dis-

tinct, sculpturation breaking line. Frontal triangle distinct. Frontal carinae sinuate with highly raised margins; central area concave with distinct frontal furrow. Sides of head in front of eyes straight, distinctly converging towards mandibular bases; behind eyes sides rounding into convex, medially emarginate occipital margin. Eyes in full face view clearly breaking lateral cephalic outline; when viewed from behind, eyes distinctly more convex laterally than medially (Fig. 7 E). Ocelli lacking. Pronotal dorsum in dorsal view with humeri armed with distinct teeth; lateral pronotal margins emarginated behind teeth and rounded posteriorly; greatest width of pronotal dorsum at about mid-length of segment. Mesonotal dorsum with lateral margins raised and converging posteriorly; anterior corners narrowly and posterior corners widely rounded. Propodeal dorsum virtually parallel sided with lateral margins terminating posteriorly in very distinct, upturned, acute teeth; posterior margins of teeth continued inwards and somewhat downwards for a short distance, failing to meet in middle where propodeal dorsum meets vertical declivity in an uninterrupted curve. Petiole armed with two strong, relatively long, dorsolaterally and posteriorly directed spines; apices of spines very weakly diverging in dorsal view, almost parallel; dorsal margin between spines with two, rather indistinct, blunt tuberculae. Anterior face of first gastral segment shallowly concave, distinctly higher than dorsal petiolar margin.

Mandibles very finely reticulate with numerous piliferous pits. Head, mesosoma and petiole rather distinctly reticulate-punctate. Gaster more finely sculptured, very closely punctate. Sculpturation on pronotal and mesonotal dorsa somewhat more longitudinally directed. Antennal scapes and legs finely reticulate-punctate.

Mandibular masticatory borders with a few, curved, rather short, golden hairs. Truncate portion of anterior clypeal margin with single, long, anteriorly directed seta medially and distinct fringe of very short setae laterally. Antennal scapes with a few, short hairs fringing apices. Fore coxae and gaster apically and ventrally with several, relatively long, erect hairs. Dorsal surfaces of head, mesosoma, petiole and gaster, except apical antennal segments, completely hairless. White, closely appressed pubescence on clypeus, anterior face of fore coxae and ventral aspect of gaster, where it is somewhat longer and rather diluted; pubescence vitually absent elsewhere.

Colour. Black, with narrow, transverse, light reddish band at bases of mandibular teeth. Antennae and legs very dark reddish-brown with condylae, tip of last funicular segments, distal margins of trochanters and apical tarsal segments light, yellowish-brown.

Sexuals and immature stages unknown.

REMARKS. In general appearance, *P. neglecta* is rather similar to *P. fruhstorferi* and the most obvious difference between the species is their relative size (HL 1.53-1.75 in *P. neglecta* versus HL 1.34-1.40 in *P. fruhstorferi*). The eyes in *P. neglecta* are distinctly more convex laterally, which is most evident when they are viewed from behind, while the eyes are evenly convex and somewhat larger in *P. fruhstorferi*. The petiolar spines are distincly stronger, longer and more posteriorly curved in *P. neglecta*, while they are more stubby and dorsally directed in *P. fruhstorferi*. *Polyrhachis neglecta* is almost uniformly black, with only the appendages very dark, reddish-brown. In contrast, the body in *P. fruhstorferi* is black, with the mandibles, antennae, legs and gaster medium reddish-brown. All the dorsal body surfaces in *P. neglecta* are virtually devoid of pilosity, while in *P. fruhstorferi* the dorsal surfaces of the head and gaster bear numerous, short erect hairs. *Polyrhachis fruhstorferi* also has the dorsum of gaster covered with a distinct pile of short, appressed hairs that are lacking in *P. neglecta*.

39. Polyrhachis sulawesiensis sp. nov.
(FIG. 7G-H)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Dumoga-Bone NP, 400m, 11.ii.1985, fog., N.E. Stork et al. (worker). PARATYPES: data as for holotype (worker); ditto, 230m, 11.vii.1985, fog., N.E. Stork et al. (worker); ditto, 7.vi.1985, N.E. Stork et al. (worker). Type deposition: Holotype and paratype in BMNH; 1 paratype each in MCZC and QM.

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 7.36, 6.95-7.76; HL 1.87, 1.87-1.90; HW 1.56, 1.53-1.56; CI 83, 81-82; SL 1.78, 1.75-1.84; SI 114, 114-118; PW 1.28, 1.29-1.37; MTL 1.93, 1.93-2.06 (4 measured).

Anterior clypeal margin with shallow, medially notched flange, laterally flanked by distinct, blunt denticles. Clypeus with poorly defined, blunt, median carina; clypeus straight in profile with weakly impressed anterior margin, posteriorly rounding into shallow basal margin, laterally indicated by a thin line breaking sculpturation.

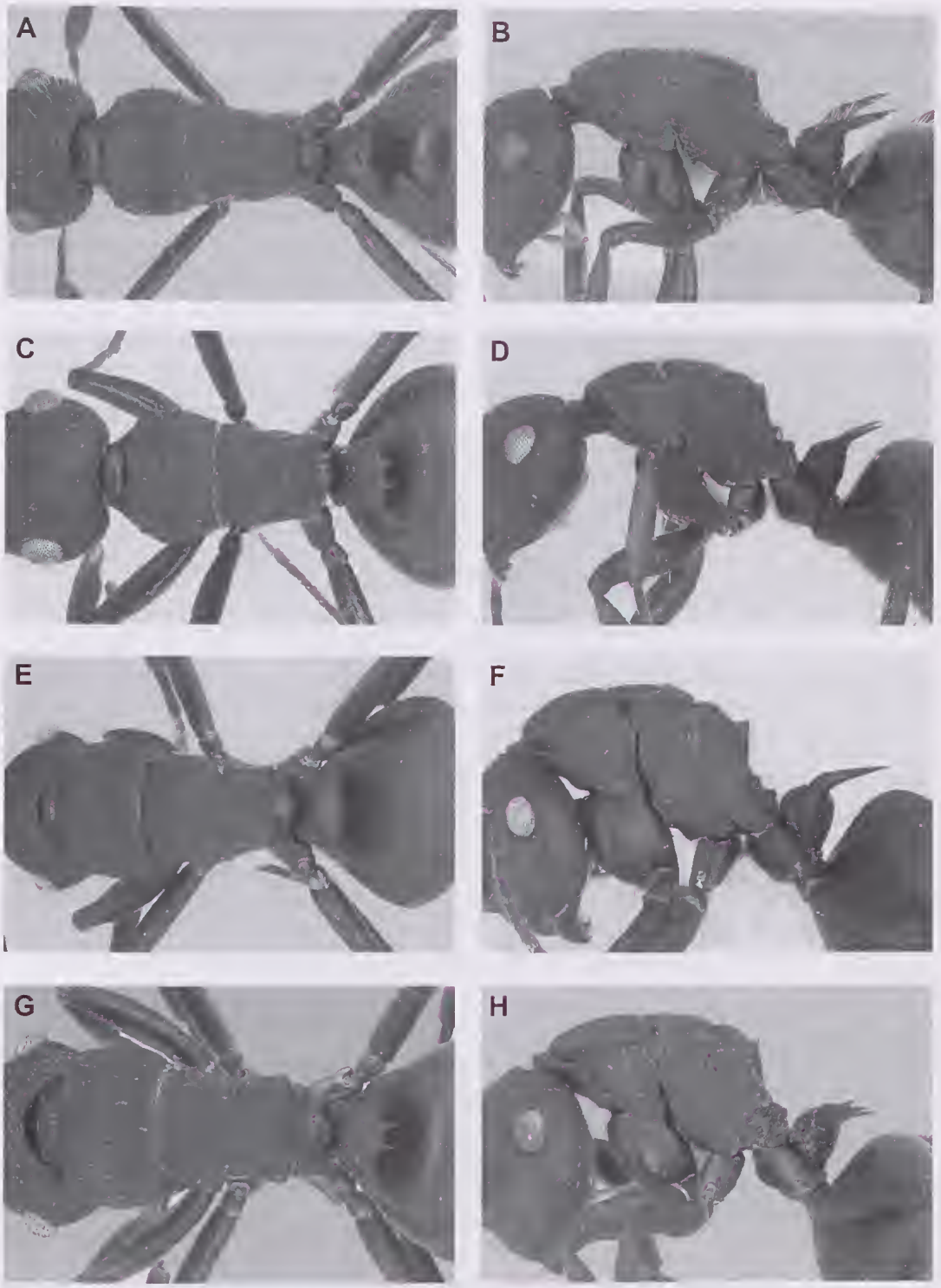

FIG. 7. *Polyrhachis* (*Myrmatopa*) species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. chaita* sp. nov.; C-D, *P. hilaris* sp. nov.; E-F, *P. neglecta* sp. nov.; G-H, *P. sulawesiensis* sp. nov. (not to scale).

Frontal triangle distinct. Frontal carinae sinuate with margins only weakly raised; central area shallow with weakly impressed frontal furrow. Sides of head in front of eyes straight, converging towards mandibular bases; behind eyes sides rounding into convex, medially narrowly emarginated, occipital margin. Eyes convex, in full face view distinctly exceeding lateral cephalic outline; more convex laterally than medially, notably when viewed from behind. Ocelli lacking. Mesosoma with pronotal and propodeal dorsa distinctly wider than dorsum of mesonotum. Pronotal humeri angular with lateral margins weakly and narrowly emarginate behind angles, rounded posteriorly; greatest width of pronotal dorsum at or just behind mid-length of segment. Propodeum distinctly transverse, wider than long; anterior propodeum distinctly wider than posterior width of mesonotum; lateral propodeal margins terminating posteriorly in short, upturned teeth; posterior margins of teeth continued inwards and somewhat downwards for a short distance but not meeting; propodeal dorsum descending into vertical declivity in medially uninterrupted line. Petiole armed with a pair of dorsolaterally directed, divergent lateral spines and a pair of very distinct, acute, intercalary spines arising from dorsal margin medially. Anterior face of first gastral segment rather flat, only marginally higher than height of petiole, with anterodorsal margin widely rounding onto dorsum.

Mandibles very finely reticulate with numerous piliferous pits. Head, mesosoma and petiole rather coarsely reticulate-rugose; gaster finely reticulate-punctate. Sculpturation somewhat longitudinally directed on pronotal dorsum, distinctly irregular elsewhere. Antennal scapes and legs reticulate-punctate.

Mandibular masticatory borders with several curved, golden hairs. Anterior clypeal margin fringed with several rather short, anteriorly directed setae. Two pairs of very short, erect hairs along frontal carinae and single pair of anteriorly directed, very short hairs on vertex. A few very short, erect hairs fringing apices of antennal scapes and a few slightly longer hairs arising from anterior faces of fore coxae. Several distinctly longer, erect hairs on ventral surface of gaster and fringing gastral apex.

Colour. Black, with appendages and gaster very dark reddish-brown. Mandibular teeth, condylae, extereme tip of apical funicular segments and trochanters mostly reddish-brown.

Sexuals and immature stages unknown.

REMARKS. *Polyrhachis sulawesiensis* is a very distinct species of *Myrmatopa* that superficially resembles some species of the subgenus *Campomyrma*. It also resembles *P. neglecta*, described above, but differs in several characters. The head and body sculpturation in *P. sulawesiensis* is reticulate-rugose and distinctly coarser than the reticulate-punctate sculpturation in *P. neglecta*. The pronotal and propodeal dorsa in *P. sulawesiensis* are distinctly wider than dorsum of the mesonotum. In contrast, the pronotal, mesonotal and propodeal dorsa in *P. neglecta* become progressively narrower posteriorly. The lateral petiolar spines in *P. sulawesiensis* are distinctly divergent and dorsum of petiole bears a pair of acute intercalary spines. The lateral petiolar spines in *P. neglecta* are longer, more strongly posteriorly directed and are almost parallel at their tips, and the dorsal petiolar margin has a pair of rather indistinct tuberculae.

Polyrhachis schang species-group

KEY TO *SCHANG*-GROUP SPECIES
(based on workers)

1. Frontal carinae distinctly elevated (in copal) ..... *excitata* Viehmeyer
   Frontal carinae not distinctly elevated 2
2. Larger species (HL 1.62-1.84); whole body more-or-less uniformly orange with yellowish or light brownish tint (Fig. 11A, B) ..... *mellita* sp. nov.
   Smaller species (HL 1.53-1.57); body light yellowish-brown and diffusely blotched with dark reddish-brown ..... *alata* Forel

40. Polyrhachis alata Forel, 1904

Polyrhachis gracilis r. *alata* Forel, 1904: 177. Holotype worker. Type locality: INDONESIA, SULAWESI, Patuhuang (H. Fruhstorfer), MHNG (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, nr Danau Mooat, 1100m, 1.viii.1985, coffee fog., (N.E. Stork et al.) (w). SULAWESI TENGAH: Lore Lindu NP, Toro, Foot of Gn. Kamanua, 845m, 28.iv.2005, cacao agrof., fog. (M.M. Bos #27) (w); ditto, Toro, Baloli, 835m, 14.iv.2005, cacao agrof., fog. (M.M. Bos #48) (w).

REMARKS. *Polyrhachis alata* was discussed in relation to the Dumoga-Bone specimens by Kohout (1998). It differs from the very similar *P. schang* Forel 1879, in having higher and more acute dorsolateral mesonotal prominences, higher

and longer and more slender petiolar spines, and by its conspicuous bicoloured pattern.

41. Polyrhachis excitata Viehmeyer, 1913

Polyrhachis excitata Viehmeyer, 1913: 147, fig. Holotype worker. Type locality: INDONESIA, SULAWESI (in copal), MNHU (examined).

Polyrhachis schang var. *excitata* Viehmeyer. Viehmeyer, 1914: 48, fig. 8. Reduced in rank to variety of *P. schang*.

Polyrhachis excitata Viehmeyer; Kohout, 1998: 507. Status reversal.

REMARKS. The holotype from copal is apparently the only specimen of *P. excitata* known. Its status and distinguishing characters were discussed by Kohout (1998).

42. Polyrhachis mellita sp. nov. (FIG. 11A-B)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Sulawesi Utara, Dumoga-Bone NP, 400m, 11.ii.1985, fog., N.E. Stork et al. (worker). PARATYPES: data as for holotype (8 workers); ditto, 11.ii.1985 (worker). Type deposition: Holotype and (3) paratypes in BMNH, 2 paratypes each in ANIC, MCZC and QM. ADDITIONAL MATERIAL. SULAWESI TENGAH: Lore Lindu NP, Toro, Foot of Gn. Kalabui, 815m, 19.iv.2005, cacao agrof., fog. (M.M. Bos #13, 38) (w, ♀); ditto, Toro, Foot of Bulu Lonca, 830m, 30.iv.2005, cacao agrof., fog. (M.M. Bos #13) (w); ditto, Dusun Tuju, 815m, 3.v.2005, cacao agrof., fog. (M.M. Bos #13) (w); ditto, Toro, Haloda, 815m, 21.iv.2005, cacao agrof., fog. (M.M. Bos #13) (w); ditto, Toro, Baloli, 835m, 14.iv.2005, cacao agrof., fog. (M.M. Bos #38) (♀); ditto, Toro, Kaha, 920m, 15.iv.2005, cacao agrof., fog. (M.M. Bos #38) (♀); ditto, Toro, Foot of Gn. Kamanua, 845m, cacao agrof., fog. (M.M. Bos #38) (♀); ditto, Toro, Watu Bohe, 860m, 14.iv.2005, cacao agrof., fog. (M.M. Bos #38) (♀).

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 7.00, 6.40-7.51; HL 1.75, 1.62-1.84; HW 1.28, 1.15-1.31; CI 73, 70-72; SL 2.62, 2.31-2.71; SI 205, 207-214; PW 0.97, 0.69-0.90; MTL 2.68, 2.34-2.90 (10 measured).

Anterior clypeal margin with rather narrow, widely emarginate median flange, flanked laterally by distinct, acute denticles. Clypeus in profile only very weakly convex, rounding posteriorly into moderately impressed basal margin, laterally margin indicated by a thin line. Frontal triangle weakly indicated. Frontal carinae with raised margins sinuate anteriorly, parallel posteriorly; central area concave with poorly indicated frontal furrow. Sides of head in front of eyes converging in virtually straight line into mandibular bases; behind eyes sides strongly converging into rather narrow occipital margin. Eyes convex, in full face view clearly breaking lateral cephalic outline. Pronotum with lateral margins indistinct; mesonotum laterally marginate, margins strongly raised dorsally, forming elevated ridges. Propodeum with lateral margins narrowly raised anteriorly, weakly converging and terminating posteriorly in elevated, dorsally rounded angles; propodeal dorsum descending into steep declivity in medially uninterrupted curve. Petiole with a pair of relatively long, slender, only weakly diverging lateral spines with dorsal margin between them concave. Anterior face of first gastral segment widely rounding onto dorsum.

Mandibles finely reticulate-rugose at bases; sculpture distinctly finer and polished towards masticatory borders. Head, mesosoma and gaster very finely shagreened; intensity of sculpturation increasing posteriorly and laterally, with mesonotal and propodeal dorsa, sides of mesosoma and petiole distinctly reticulate-punctate.

Mandibular masticatory borders with numerous, semierect, golden hairs and numerous very short appressed hairs towards bases. Anterior clypeal margin with long median seta and numerous short setae lining margin laterally. A few paired short, erect hairs near anterior and basal clypeal margins and along frontal carinae. Gaster with numerous, relatively long, erect hairs lining margins of ventral segments and fringe of hairs at gastral apex. Extremely short, closely appressed, golden pubescence in various densities over all dorsal body surfaces.

Colour. Body uniformly yellow, with a light brownish tint in some specimens. Antennae and legs yellowish-brown. Masticatory borders, inner mandibular margins, frontal carinae, pronotal collar, lateral margins of mesonotal and propodeal dorsa and ventral margins of meso- and metapleurae narrowly bordered with dark brown.

Sexuals and immature stages unknown.

REMARKS. *Polyrhachis mellita* is relatively similar to *P. leviuscula*, described by Viehmeyer (1916) from Singapore. However, while the head and pronotal dorsum are very smooth and highly polished in *P. leviuscula*, they are finely sculptured in *P. mellita*. The pronotal dorsum in lateral view is evenly convex in *P. leviuscula*, while it is distinctly flatter in *P. mellita*. The anterior face of the petiole in *P. mellita* is very low and, in lateral view, rounds smoothly onto its dorsum, forming a continuous plane with the petiolar spines (Fig. 11B). In contrast, the anterior face of petiole in *P. leviuscula* is higher and more

angular in lateral view, with spines arising from petiolar dorsum at a distinct angle. The available specimens of *P. leviuscula* (including a syntype) are somewhat smaller (HL <1.62) than *P. mellita* (HL > 1.62) and are more yellow-orange in colour compared to the distinctly lighter, uniformly yellow *P. mellita*.

Polyrhachis wallacei species-group

KEY TO *WALLACEI*-GROUP SPECIES
(based on workers)

1. Body and appendages covered with rather abundant, semierect to erect, bristle-like hairs (Fig. 11C, D) ..... *hispida* sp. nov.

   Body and appendages with only a few erect hairs on head and apical segments of gaster 2

2. Pronotal humeri produced into blunt, minute teeth; body mostly light to medium yellowish-brown. . *wallacei* Emery

   Pronotal humeri rounded without an indication of humeral teeth; body very dark reddish-brown, with sides of mesosoma, propodeum and petiole virtually black (Fig. 11E, F) ..... *kazuoi* sp. nov.

43. Polyrhachis hispida sp. nov.
(FIG.11C-D)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Dumoga-Bone NP, nr Danau Mooat, 1100m, I.viii.1985, coffee fog., N.E. Stork et al. (worker). Type deposition: Unique holotype in BMNH.

DESCRIPTION. *Worker*. Dimensions: TL c. 5.19; HL 1.37; HW 1.15; CI 84; SL 1.62; SI 141; PW 0.72; MTL 1.81 (1 measured).

Anterior clypeal margin with median, relatively wide, shallowly and widely emarginate flange, flanked laterally by distinct, acute denticles. Clypeus with strong, distinctly raised median carina; in profile clypeus straight, very shallowly impressed anteriorly, posteriorly rounding into well impressed basal margin, laterally indicated by sculpture-breaking line. Frontal triangle weakly indicated. Frontal carinae sinuate with narrowly raised margins; central area wide with frontal furrow only weakly indicated. Sides of head in front of eyes straight, converging anteriorly towards mandibular bases; behind eyes sides rounding into convex occipital margin. Eyes convex, relatively large, in full face view clearly breaking lateral cephalic outline. Ocelli lacking. Pronotum in dorsal view with evenly rounded lateral margins that are poorly indicated posteriorly. Dorsum of mesosoma with lateral margins very weakly raised and converging posteriorly. Metanotal groove forming a thin, posteriorly bowed line. Propodeum with lateral margins terminating in upturned, acute teeth; inner margins of teeth continued medially and meeting, forming a short, rather weak, transverse ridge, separating propodeal dorsum from declivity. Petiole with anterior and posterior faces virtually straight; dorsum armed with a pair of slender, acute, dorsolaterally directed, widely diverging spines. Anterior face of first gastral segment distinctly higher than full height of petiole, widely rounding onto dorsum.

Mandibles very finely striate at bases; very smooth and polished towards masticatory borders with numerous piliferous pits. Head, mesosoma and petiole mostly finely reticulate-punctate with sculpturation on vertex, sides of mesosoma and petiole more densely punctate. Clypeus anteriorly and laterally with reticulae longitudinally directed. Antennal scapes very densely reticulate-punctate. Pronotal dorsum with irregular longitudinal striate that curve outwards posteriorly. Mesonotum more regularly, longitudinal striate; propodeal dorsum reticulate-punctate. Legs, including coxae, rather shallowly reticulate punctate. Gaster finely shagreened, rather polished.

Mandibles with numerous, short and medium length, curved, golden hairs. Anterior clypeal margin with one long seta medially and numerous short setae fringing margin laterally. Antennae, including funiculi, with numerous short and medium length, mostly erect hairs. Front of head with numerous, rather long hairs, some almost as long as greatest diameter of eye; hairs erect on clypeus and somewhat anteriorly curved along frontal carinae and on vertex. Numerous, semierect hairs fringing outline of head in full face view. Pronotal and mesonotal dorsa with numerous erect hairs, a little shorter than those on dorsum of head. Propodeum with very short, semierect, anteriorly directed hairs on dorsum; declivity with hairs lacking, smooth and polished. Gaster with abundant, relatively long hairs over all surfaces, except anterior face. Relatively long, appressed and decumbent, golden pubescence in various densities over all dorsal surfaces of head; somewhat shorter, more silvery pubescence on dorsum of mesosoma; gastral dorsum with rather dense, white-greyish pubescence.

Whole body distinctly orange; head, notably upon vertex, and sides mesosoma with reddish hue. Dorsum of first gastral segment paler, yellowish-orange. Outer and masticatory margins of mandibles, anterior clypeal margin, frontal carinae, pronotal collar and ventral margins of meso- and metathoracic sternites narrowly bordered with dark brown.

REMARKS. *Polyrhachis hispida* is most similar to *P. wallacei* Emery, however, it differs in having the body covered with abundant, relatively long, hairs.

44. Polyrhachis kazuoi sp.nov. (FIG. 11E-F)

MATERIAL. HOLOTYPE: SULAWESI SELATAN, Mt Kaleakan, Tana Traja, 02°58'S, 119°54'E, 1080-1140m, 17.x.1999, K. Ogata & K. Masaoka #57 (worker). PARATYPES: data as for holotype (2 workers). Type deposition: Holotype in QM (QMT144151), 1 paratype each in BMNH and MCZC.

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL e. 5.74, 5.39-5.74; HL 1.47, 1.43-1.47; HW 1.25, 1.18-1.25; CI 85, 82-85; SL 1.84, 1.72-1.84; SI 147, 146-148; PW 0.87, 0.81-0.87; MTL 1.93, 1.78-1.93 (3 measured).

Anterior clypeal margin with median truncatation flanked laterally by distinct, acute denticles. Clypeus with poorly defined, blunt median carina; in profile clypeus weakly convex posteriorly narrowly rounding into relatively shallow basal margin, laterally margin indicated by a sculpture-breaking line. Frontal triangle distinct. Frontal carinae sinuate with narrowly raised, well separated margins; central area rather wide; frontal furrow clearly impressed. Sides of head in front of eyes straight, converging anteriorly towards mandibular bases; behind eyes sides rounding into convex occipital margin. Eyes convex, relatively large, in full face view clearly breaking lateral cephalic outline. Ocelli lacking; positions indicated by shallow punctures in sculpturation. Pronotal dorsum with poorly defined median depression; lateral pronotal margins narrowly rounding into distinct promesonotal suture. Dorsum of mesosoma with lateral margins converging into distinct, posteriorly bowed, metanotal groove. Propodeum with lateral margins terminating in short, upturned, weakly diverging, acute spines. Petiole with anterior and posterior face straight, parallel in lateral view; dorsum virtually flat, armed with a pair of slender, acute, widely diverging spines. Anterior face of first gastral segment distinctly higher than full height of petiole, widely rounding onto dorsum .

Mandibles very finely, longitudinally striate with numerous piliferous pits. Head densely reticulate-punctate with sculpturation on clypeus and central area somewhat finer. Pronotal dorsum with irregular longitudinal striae that curve outwards posteriorly. Mesonotum regularly, longitudinally striate. Sides of mesosoma, propodeal dorsum and petiole distinctly reticulate-punctate. Gaster finely shagreened, rather polished.

Mandibles with numerous curved, medium length, golden hairs near mastieatory borders and numerous short, appressed hairs towards mandibular bases. Anterior clypeal margin with a long median seta and numerous short setae fringing margin laterally. Several medium length, paired hairs near anterior and basal clypeal margins, along frontal carinae and single pair on vertex. Two long hairs on anterior faces of fore coxae; single shorter hairs on venter of trochanters and femora. Gaster with several medium length hairs lining posterior margins of apical segments, hairs more numerous over gastral venter.

Generally medium reddish-brown with mandibles, clypeus and central area distinctly lighter. Mandibular teeth and antennae, except apical segments, dark reddish-brown. Frontal carinae narrowly lined with black. Mesosoma becoming progresively darker posteriorly, with sides of mesonotum, propodeum, petiole and coxae very dark, almost black. Legs dark reddish-brown with trochanters and apical tarsal segments a shade lighter. Gaster medium reddish-brown, with posterior margins of segments widely lined with dark brown.

REMARKS. *Polyrhachis kazuoi* is relatively similar to *P. wallacei*, sharing with that species the characteristics of the *wallacei*-group, including a lack of lateral mesonotal prominences and indistinct pronotal margins. However, the pronotum of *P. wallacei* has minute humeral teeth that are completely lacking in *P. kazuoi*. The pronotal and mesonotal dorsa are very finely, longitudinally striate in *P. kazuoi*, while in *P. wallacei* the whole dorsum of the body is irregularly, shallowly reticulate. The body of *P. wallacei* is light to medium yellowish-brown with the clypeus distinctly lighter. In contrast, *P. kazuoi* is generally darker, reddish-brown, with the sides of mesonotum, propodeum and petiole almost black.

45. Polyrhachis wallacei Emery, 1887

Polyrhachis wallacei Emery, 1887: 223. Syntype workers, queen. Type locality: INDONESIA, SULAWESI, Kandari (O. Beccari), MCSN (examined).

MATERIAL. SULAWESI TENGAH: Lore Lindu NP, nr Dongi-Dongi shelter, 01°15'S, 120°20'E, ca 1020m, 4-9.xii.1985 (Malaise trap) (C.van Achterberg) (w); ditto, Toro, Bulu (Dusun Dua), 820m, 21.iv.2005, cacao agrof. (fog.) (M.M. Bos) (w); ditto, Watu Bohe, 860m, 25.iv.2005 cacao agrof. (fog.) (M.M. Bos) (w).

REMARKS. Specimens from Lore Lindu compare well with two available syntypes of *P. wallacei* and I am confident they are conspecific.

Subgenus **Myrmhopla** Forel, 1915

Dorow (1995) recognised sixteen species-groups, within the subgenus *Myrmhopla*. The thirty-one species of *Myrmhopla* from Sulawesi fall within ten of these (*armata*-, *bicolor*-, *cleophanes*-, *cryptoceroides*-, *dives*-, *flavoflagellata*-, *furcata*-, *hector*-, *mucronata*- and *sexspinosa*-group).

Polyrhachis armata species-group

KEY TO *ARMATA*-GROUP SPECIES (based on workers)

Polyrhachis peregrina is known only from the queen caste and is not included in the following key.

1. Head, mesosoma and petiole deeply and coarsely foveolate-rugose (Figs 8C, D) . . . *armata* (Le Guillou)

   Head, mesosoma and petiole reticulate-punctate or weakly and shallowly rugose-punctate (Figs 8A, B) 2

2. Dorsum of petiole medially with two short, acute, intercalary spines (Fig. 8A) 3

   Dorsum of petiole medially with only vague rudimentary tuberculae. . . . . *nudata* Fr. Smith

3. Propodeal spines virtually subparallel; whole body with distinct pile of pale-golden appressed pubescence . . . . . *aberrans* sp. nov.

   Propodeal spines strongly diverging; whole body with rather diluted, silvery-white appressed pubescence. 4

4. Larger species (HL >1.95); pronotal spines massive, strongly curved downwards (Fig. 8F) . . . . . *strictifrons* Emery

   Smaller species (HL <1.65); pronotal spines horizontal, rather broad, but not massive 5

5. Eyes rather flat; pronotal spines short, hardly longer than width at base; pronotal dorsum between spines distinctly rugose-punctate . . . . . *diaphanta* Fr. Smith

   Eyes convex; pronotal spines more slender, almost twice as long as width at base; pronotal dorsum uniformly and finely reticulate-punctate. . . . *saevissima* Fr. Smith

46. Polyrhachis aberrans sp. nov. (FIG. 8A-B)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Dumoga-Bone NP, 400m, 11.ii.1985, fog., N.E. Stork et al. (worker). PARATYPES: data as for holotype (5 workers); ditto, 230m, 11.vi.1985, fog., N.E. Stork et al. (2 workers); ditto, 230m, 30.ix.1985, fog., N.E. Stork et al. (2 workers); ditto, Subcamp Barney's, 300m, x.1985 (Bosmans & Van Stalle #022) (w). Type deposition: Holotype and (5) paratypes in BMNH, 2 paratypes each in ANIC, MCZC and QM, 1 paratype in IRSN.

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 7.46, 6.60-8.06; HL 1.68, 1.56-1.89; HW 1.34, 1.27-1.47; CI 80, 78-81; SL 2.28, 2.09-2.50; SI 170, 164-173; PW 1.25, 1.18-1.43; MTL 2.37, 2.18-2.62 (10 measured).

Anterior clypeal margin with medially notched, truncate flange, flanked laterally by acute angles. Clypeus with distinct, posteriorly raised median carina, terminating just short of basal margin; in profile clypeus straight with basal margin well impressed, laterally basal margin indicated by obscure, thin line. Frontal triangle indistinct. Frontal carinae sinuate with moderately raised margins; central area relatively wide and shallowly concave with frontal furrow weakly indicated. Sides of head in front of eyes converging anteriorly in virtually straight line; behind eyes sides rounding into convex occipital margin. Eyes convex, in full face view clearly breaking lateral cephalic outline. Ocelli lacking. Pronotum armed with pair of anterolaterally and weakly downward-directed acute spines. Propodeum with pair of strong, horizontal, posteriorly directed, acute spines. Petiole with anterior face straight, abruptly rounding onto dorsum; posterior face strongly convex; dorsum armed with a pair of lateral, widely diverging, horizontal spines; bases of spines clearly situated below summit of dorsum; apices of spines strongly curved downwards and weakly outwards; dorsum of petiole also with pair of slender, acute, horizontally and posteriorly directed intercalary spines with their tips curved downwards. Subpetiolar process acute anteriorly, widely rounding posteriorly. Anterior face of first gastral segment distinctly lower than height of petiole, widely rounding onto dorsum.

Mandibles finely reticulate-rugose with numerous piliferous pits. Head, mesosoma, petiole and gaster shagreened with summit of pronotum and mesonotum distinctly coarsely punctate. Sculpturation increasing in intensity laterally with sides of mesosoma and petiole reticulate-punctate. Apices of spines rather smooth and polished.

Mandibular masticatory borders with only a few, curved hairs and numerous very short appressed hairs arising from pits. Anterior clypeal margin with 3 long, anteriorly directed setae and several short setae fringing margin laterally. A few pairs of hairs near anterior and basal clypeal margins, along frontal carinae and a single pair on vertex. A very few erect hairs on fore coxae and single hair arising from ventral surface of each trochanter and femur. Gaster with medium length, golden, erect hairs lining posterior margins of apical gastral segments with hairs more abundant dorsally. Body with relatively

long, mostly appressed, pale golden, pubescence; most abundant on head and dorsum of mesosoma, but rather diluted on vertex, midline and posterior half of mesonotal dorsum. Pubescence almost completely absent from summit of pronotal dorsum and tips of spines. Gastral dorsum with pubescence shorter, more closely appressed and dense, almost completely hiding underlying sculpturation.

Colour. Black; mandibles black with narrow band across masticatory borders and apical teeth reddish-brown. Funiculi with distal segments progressively lighter and tip of apical segment yellowish-brown. Tibiae light reddish-brown, except proximal ends narrowly black.

Sexuals and immature stages unknown.

REMARKS. Direct comparison of *P. aberrans* workers with the unique holotype queen of *P. peregrina* Fr. Smith (OXUM) has shown them to be superficially very similar. Both species have the characteristic appressed, pale golden pubescence, which is particularly distinct on the sides of the mesosoma and the propodeal dorsum, petiole, gaster and spines (except their extreme tips). However, they distinctly differ in a number of characters on the head. The frontal carinae in *P. aberrans* are only moderately elevated, with the central area relatively wide and shallowly concave. In contrast the frontal carinae in *P. peregrina* are prominent and markedly closer together, creating a very narrow and deeply excavated central area. The eyes in *P. aberrans* are moderately convex, clearly breaking the lateral outline of the head in full frontal view, while in *P. peregrina* the eyes are weakly convex, barely breaking the lateral cephalic outline. The clypeus in *P. aberrans* features a distinct, posteriorly raised, median carina that terminates just short of the deeply impressed basal margin. In *P. peregrina* the median clypeal carina is feebly indicated posteriorly and, in profile, the basal clypeal margin is only shallowly impressed. In addition, the pronotal spines in *P. aberrans* are moderately divergent and longer than their basal widths, while in *P. peregrina* they are short, only slightly longer than their basal widths and strongly turned outwards and curved downwards. The shape of the petiole is almost identical in both species, featuring a narrow dorsal margin and posteriorly divergent, almost arrow-shaped spines. The propodeal spines are relatively long and somewhat downturned in *P. aberrans*, but distinctly shorter and straight in *P. peregrina*. In both species the dorsum of the petiole bears two short, acute, posteriorly directed intercalary spines that are much closer together in *P. aberrans*. Both species are black, but *P. aberrans* has the extreme tips of the apical antennal segments and the tibiae, except their proximal ends, light reddish-brown.

47. Polyrhachis armata (Le Guillou, 1842) (FIG. 8C-D)

Formica armata Le Guillou, 1842: 313. Holotype queen. Type locality: PHILIPPINES, MINDANAO, Zamboanga, ?MNHN (type presumed lost).

Polyrhachis armata (Le Guillou); Roger, 1863: 9.

REMARKS. This is a relatively common species that extends from the Andaman Islands and Indo-China, including Myanmar, Peninsular Malaysia, Singapore, Thailand and Vietnam, eastwards to the Philippines and south to Borneo, Sumatra and Java. It was listed from Sulawesi by Emery (1901), however, I have not seen any specimens originating from east of Wallace's line.

48. Polyrhachis diaphanta Fr. Smith, 1861

Polyrhachis diaphantus Fr. Smith, 1961: 40, pl. 1, fig. 12. Holotype worker. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 230m, 2.xii.1985, fog. (N.E. Stork et al.) (w). SULAWESI TENGAH: Lore Lindu NP, Toro, Gn. Kamonua, 1080m, 20.iv.2005, nat. for., fog. (M.M. Bos #43, 41) (w, ♀); ditto, Toro, Gn. Kalabui, 950m, 5.v.2005, nat. for., fog. (M.M. Bos #43) (w); ditto, Toro, Bulu Lonca, 1130m, 29.iv.2005, nat. for., fog. (M.M. Bos #43) (w).

REMARKS. *Polyrhachis diaphanta* was considered by Emery (1900) to be a junior synonym of *P. acantha* Fr. Smith and later (1925) as a variety of that species. Donisthorpe (1932) regarded *P. diaphanta* a valid species and, after examining the primary types of all the relevant species, including *P. acantha*, *P. acasta*, *P. saevissima* and *P. romanovi*, I came to the same conclusion (Kohout, 1998).

49. Polyrhachis nudata Fr. Smith, 1860

Polyrhachis nudatus Fr. Smith, 1860a: 71. Holotype worker. Type locality: INDONESIA, SULAWESI, Makassar (A.R. Wallace), OXUM (examined).

MATERIAL. SULAWESI UTARA: Domoga-Bone NP, 230m, 5.v.1985, fog., (N.E. Stork et al.) (w); ditto, 30.ix.1985, fog. (N.E. Stork et al.) (w). SULAWESI TENGAH: Lore Lindu NP., Toro, Bulu Lonca, 1130m, 27.iv.2005, nat. for., fog. (B.B. Bos #24) (w); ditto, Toro, Kauboga, 840m, 4.v.2005, cacao agrof., fog. (M.M. Bos #31) (w); ditto, Toro, Gn. Kamonua, 1080m, 20.iv.2005, nat. for., fog. (M.M. Bos #22) (♀); ditto, Toro, Gn. Kalabui, 950m, 16.iv.2005, nat. for.,

fog. (M.M. Bos #22) (♀). SULAWESI TENGGARA: nr Sanggona, Base Camp, Gng Watuwila, e. 200m, 13.-15.x.1989 (Malaise trap) (C.van Achterberg) (w); 1-2km E of Wolasi, 42km S of Kendari, e. 350m, rf, 13-14.vii.1972 (W.L. Brown) (w). SULAWESI SELATAN: Balampesoang For., 5-8km NE of Tanete, 400m, degr. rf., 8-10.vii.1972 (W.L. Brown) (w); Karaentha, 05°0.2'S, 119°44'E, 270m, 23.x.1999 (K. Ogata & K. Masaoka #100) (w).

REMARKS. The examined specimens listed above compare well with the *P. nudata* holotype.

50. Polyrhachis peregrina Fr. Smith, 1860

Polyrhachis peregrinus Fr. Smith, 1860a: 71. Holotype queen. Type locality: INDONESIA, SULAWESI, Makassar (A.R. Wallace), OXUM (examined).

REMARKS. *Polyrhachis peregrina* is very similar to *P. aberrans* described above and their relationship is discussed in detail under that species. No worker specimens comparable with the unique holotype queen were found in the material available for this study.

51. Polyrhachis saevissima Fr. Smith, 1860

Polyrhachis saevissimus Fr. Smith, 1860a: 71. Holotype worker. Type locality: INDONESIA, SULAWESI, Makassar (A.R. Wallace), OXUM (examined).

Polyrhachis acantha Fr. Smith, 1860b: 98, pl. 1, fig. 16. Holotype worker. Type locality: INDONESIA, Batjan I. (A.R. Wallace), OXUM (examined). Synonymy by Bolton, 1974: 178.

(For full synonymy citations see Bolton, 1974: 178 and 1995: 356.)

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 25.ii.1985 (mangrove fog. (N.E. Stork et al.) (w); ditto, 25.ii.1985 (N.E. Stork et al.) (w); ditto, 9.-16.v.1985 (N.E. Stork et al.) (w); mid vi.-4.vii.1985, Tumpah R., for. edge (N.E. Stork et al.) (w); Gn. Ambang F.R., nr Kotamobagu, 1200m, 18.ii.1985, fog. (N.E. Stork et al.) (w). SULAWESI TENGAH: nr Luwuk, Bunga, e. 300m, 21.-31.x.1989 (C.van Achterberg) (w); ditto, 1.-14.xi.1989 (C.van Achterberg) (w); nr Luwuk, Salodik-Linyek, 500m, 21.-31.x.1989 (C.van Achterberg) (w); Palolo Valley, Sintuwu (S1), 28.vi.2001 (J. Ketterl #Ants sp. 5) (w); ditto, except (S3), 29.vi.2001 (J. Ketterl #Ants sp. 16) (♀); Lore Lindu NP, Toro, Gn. Kalabui, 950m, 5.v.2005, nat. for., fog. (M.M. Bos #43) (w); ditto, Toro, Bulu Lonca, 1130m, 29.iv.2005, nat.for., fog. (M.M. Bos #43) (w); ditto, Toro, Powawua, 810m, 18.iv.2005, cacao agrof., fog. (M.M. Bos #40) (w); ditto, toro, W foot of Gn. Kalabui, 825m, 17.iv.2005, cacao agrof., fog. (M.M. Bos #40) (w); ditto, Toro, Foot of Gn. Kamanua, 845m, 28.iv.2005, cacao agrof., fog. (M.M. Bos #49) (♀); ditto, Toro, Dusun Tuju, 815m, 3.v.2005, cacao agrof., fog., M.,M. Bos #40) (w); ditto, Toro, Kauboga, 840m, 4.v.2005, cacao agrof., fog. (M.M. Bos #40) (w); ditto, Toro, Haloda, 815m, 21.iv.2005, cacao agrof., fog. (M.M. Bos #40) (w). SULAWESI TENGGARA: nr Saggona, Base Camp, Gng Watuwilla, e. 200m, 13.-15.x.1989 (C.van Achterberg) (w); ditto, 15.x.-5.xi.1989 (C.van Achterberg) (w) (all specimens collected by C.van Achterberg originated from Malaise traps); Poniponiki nr Raterate, 04°02'S, 121°53'E, 100m, 13.x.1999 (K, Ogata & K. Masaoka #43) (w). SULAWESI SELATAN: Mt Kaleakan, Tana Traja, 02°58'S, 119°54'E, 1080-1140m, 17.x.1999 (K. Ogata & K. Masaoka #57) (w); Soroako, 02°32'S, 121°22'E, 100m, 21.x.1999 (K. Ogata & K. Masaoka #86) (w); Balan Ba'na nr Soroako, 02°39'S, 121°12'E, 130m, 21.x.1999 (K. Ogata & K. Masaoka #89) (w).

REMARKS. All the above listed specimens conform with the characters of this species as delimited by Bolton (1974) and further discussed by Kohout (1998). In view of its widespread distribution and variability, *P. saevissima* is either a single species with numerous variable, local populations, or it may be a complex of a number of closely related species.

52. Polyrhachis strictifrons Emery, 1898 (FIG. 8E-F)

Polyrhachis strictifrons Emery, 1898: 242, fig. 14. Syntype workers. Type locality: INDONESIA, SULAWESI, Toli-Toli (H. Fruhstorfer), MCSN (examined).

MATERIAL. SULAWESI UTARA: Kalabat, e. 250m, iii.1931 (G. Heinrich) (w). SULAWESI TENGGARA: Wolasi, Pangalulu, 04°10'S, 122°30'E, 140m, 14.x.1999 (K. Ogata & K. Masaoka #52) (w).

REMARKS. *Polyrhachis strictifrons* is a very distinct, rather rare species. The single workers from Kalabat and Wolasi are the only specimens I have ever seen in addition to the types. Both specimens are very similar to the syntypes and the only noticeable difference relates to the petiole. The lateral petiolar spines in the modern specimens diverse more strongly from their bases and their intercalary teeth are shorter than those of the syntypes. Dorow (1995: 61) followed Emery (1925: 196) in stating that *P. strictifrons* was "described on a female", however, both syntypes are workers.

Polyrhachis bicolor species-group

KEY TO *BICOLOR*-GROUP SPECIES (based on workers)

1. Distinctly bicoloured; head, mesosoma and petiole black with mandibles, antennae, legs, including coxae and gaster orange or light reddish-brow. . . . *bicolor* Fr. Smith

   Unicoloured; body black with only mandibles rusty-red and tibiae dark reddish-brown (in copal) . . *subfossa* Viehmeyer

53. Polyrhachis bicolor Fr. Smith, 1858

Polyrhachis bicolor Fr. Smith, 1858: 65. Holotype queen.

Type locality: BURMA, BMNH (examined).
(For full synonymy citation see Bolton, 1995: 344.)

MATERIAL. SULAWESI SELATAN: Pantai Tapejava nr Takalar, 05°31S, 119°26'E, sea level, 10.x.1999 (K. Ogata & K. Masaoka #28) (w).

REMARKS. The three workers from Pantai Tapejava are fairly similar to other available *P. bicolor* specimens and for the purpose of this paper I consider them conspecific. *Polyrhachis bicolor* is a widespread and relatively common species, extending from South East Asia south to Indonesia, New Guinea and Northern Australia. Across its distribution, *P. bicolor*, as currently interpreted, consists of a large number of overlapping populations that differ to varying extents from the holotype from Burma (= Myanmar). About eleven infraspecific forms are presently associated with *P. bicolor*, many clearly representing valid species. In addition, at least twice as many closely related new species are presently in collections awaiting description. This widespread and complicated group is in great need of revision but this is beyond the scope of the present paper.

54. Polyrhachis subfossa Viehmeyer, 1913

Polyrhachis subfossa Viehmeyer, 1913: 154, fig.. Holotype worker. Type locality: INDONESIA, SULAWESI (in copal), SNSD.

REMARKS. I did not have the opportunity to examine the unique holotype of *P. subfossa* but from its description and accompanying illustration it appears that it is not conspecific with any of the following *P. (bicolor)* species.

The following five taxa belong to a complex of species closely allied to *P. bicolor weyeri* Karawajew from Ambon I., and to *P. longipes* Fr. Smith from the Aru Is. Three are represented by single workers and two by single queens. They all appear to represent new species, but given the complexity of the group, they are not described here. Consequently I list them as *P. (bicolor)* sp. A, B, C, D and E and provide their collection data and a key to those species represented by workers, for future reference.

1. Body black with only mandibles and apical antennal segments yellow or light orange; relatively long, erect hairs and appressed silvery pubescence abundant over all dorsal body surfaces; pronotal spines curved upwards ..... (*bicolor*) sp. A

   Body black with mandibles and apical antennal segments yellow or light orange; gaster and femora very dark reddish-brown 2

2. Body with only relatively short, somewhat suberect, sporadic hairs; pronotal spines relatively short, straight ..... (*bicolor*) sp. B

   Body with long, erect hairs and somewhat brassy, rather diluted, appressed pubescence, except propodeal and gastral dorsa where it is more dense; pronotal spines distinctly upturned ..... (*bicolor*) sp. C

55. Polyrhachis (bicolor) sp. A

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, nr Danau Mooat, 1100m, 1.viii.1985, coffee fog. (N.E. Stork et al.) (worker).

56. Polyrhachis (bicolor) sp. B

MATERIAL. SULAWESI TENGAH: Lore Lindu NP, nr Dongi-Dongi shelter, 01°15'S, 120°20'E, ca 1000m, 4.-9.xii.1985, Malaise trap (C.van Achterberg) (worker).

57. Polyrhachis (bicolor) sp. C

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 400m, 19.vii.1985, fog. (N.E. Stork et. al.) (worker).

58. Polyrhachis (bicolor) sp. D

MATERIAL. SULAWESI TENGAH: Palolo Valley, Nopu (N5), 27.vi.2001 (J. Ketterl #Ants sp. 6) (queen).

59. Polyrhachis (bicolor) sp. E

MATERIAL. SULAWESI TENGAH: Palolo Valley, Sintuwu (S4), 29.vi.2001 (J. Ketterl #Ants sp. 17) (queen).

Polyrhachis cleophanes species-group

KEY TO *CLEOPHANES*-GROUP SPECIES (based on workers)

1. Body with numerous erect hairs; dorsum of mesosoma coarsely and deeply reticulate-rugose 2

   Body virtually without erect hairs; dorsum of mesosoma transversely wrinkled ..... *smithi* Emery

2. Pronotal spines closely approximated, width of pronotal dorsum between their bases distinctly shorter than length of spines; body black with legs reddish-brown ..... *cleophanes* Fr. Smith

   Pronotal spines situated further apart, width of pronotal dorsum between their bases distinctly greater than length of spines; body and appendages virtually black ..... *salebrosa* sp. nov.

60. Polyrhachis cleophanes Fr. Smith, 1861

Polyrhachis cleophanes Fr. Smith, 1861: 41, pl. 1, fig. 14. Holotype worker. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined).

Polyrhachis vibida Fr. Smith, 1861: 42, pl. 1, fig. 17. Holotype queen. Type locality: SULAWESI, Tonadano (A.R. Wallace), OXUM (examined). Synonymy by Forel,1911: 299.

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, Danau Mooat, nr Kotamobagu, 1200m, 25.i.1985

(N.E. Stork et al.) (w); ditto, v.1985 (N.E. Stork et al.) (w); ditto, 1100m, 31.vii.1985, *Pandanus* fog. (N.E. Stork et al.) (w); Gn. Ambang F.R., 1200m, nr Kotamobagu, 18.ii.1985, fog.) (N.E. Stork et al.) (w, ♀); Gn. Mogogonipa, 1000m, 26.iv.-22.v.1986 (N.E. Stork et al.) (w). SULAWESI SELATAN, Batu Tumonga, Tana Traja, 02°55'S, 119°53'E, 1260m, 18.x.1999 (K. Ogata & K. Masaoka # 62) (w).

REMARKS. The specimens listed above are closely comparable with the holotype of *P. cleophanes* and I consider them conspecific.

61. Polyrhachis salebrosa sp. nov. (FIG. 8G-H)

MATERIAL. HOLOTYPE: SULAWESI SELATAN, Kayulagi nr Mangktana, 02°23'S, 120°47'E, 600m, 20.x.1999, K. Ogata & K. Masaoka # 79) (worker). PARATYPE: data as for holotype (1 worker). Type deposition: Holotype in QM (QMT144155); paratype in MCZC.

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 8.16, 8.57; HL 2.06, 2.12; HW 1.56, 1.62; CI 76, 76; SL 2.46, 2.59; SI 158, 160; PW 0.90, 0.97; MTL 2.68, 2.78 (2 measured).

Anterior clypeal margin with narrow, median incision. Clypeus with distinctly elevated median carina and depressions running on both sides parallel with anterior margin; clypeus straight in profile with shallowly impressed basal margin, laterally basal margin indicated by a thin, sculpture-breaking line. Frontal triangle indistinct. Frontal carinae sinuate, with highly elevated, laminate margins; central area deeply excavated with frontal furrow replaced anteriorly by rather distinct carina. Sides of head in front of eyes weakly convex, converging towards mandibular bases; behind eyes sides rounding into highly convex occipital margin. Eyes relatively small and highly convex, protuberant; in full face view clearly breaking lateral cephalic outline. Ocelli lacking. Pronotal dorsum convex; humeri armed with pair of spines that arise well inside the lateral pronotal outline in dorsal view; spines projecting dorsolaterally then curving forward and weakly downward. Mesonotum convex in outline; metanotal groove somewhat concealed by overlying sculpturation. Propodeal dorsum with acute, dorsolaterally and posteriorly directed spines, their inner margins forming an evenly curved 'U'-shape in frontal view; propodeal declivity oblique in lateral view. Petiole biconvex in profile; anterior face with distinct teeth near base; dorsum armed with pair of slender, acute, dorsolaterally and posteriorly directed, divergent spines with their bases situated below summit of transversely convex dorsum. Anterior face of first gastral segment widely rounding onto dorsum.

Mandibles with a few longitudinal striae near masticatory borders, rather smooth and polished towards bases with very shallow piliferous pits. Clypeus distinctly reticulate-punctate with several deep punctures. Laminate margins of frontal carinae very finely punctate, rather polished. Head, mesosoma and petiole very coarsely and deeply reticulate-rugose, almost foveolate in parts. Antennal scapes and legs very densely reticulate-punctate. Spines rather smooth and polished. Gaster very finely punctate and highly polished on exposed surfaces.

Mandibles with a number of short, curved, golden hairs at masticatory borders and more erect hairs along outer margins. Anterior clypeal margin with a few long and several short, golden setae, with distinct reddish tint, medially. Antennae with numerous, relatively short, erect hairs along leading edges and a few hairs along inferior margins. Whole body, including gaster and legs, with abundant medium length, mostly erect, variously curved, whitish or pale golden hairs, longest hairs almost equal to greatest diameter of eye. Relatively abundant, somewhat uneven and rough, rather long, appressed, silvery and white pubescence on dorsal body surfaces, except tips of spines. Pubescence on gastral dorsum medially converging; both specimens with pubescence missing from various parts of dorsum, notably from shoulders of first gastral segment, probably due to abrasion.

Colour: Black; mandibular teeth, condylae and extreme tips of apical funicular segments reddish-brown.

Sexuals and immature stages unknown.

REMARKS. *Polyrhachis salebrosa* is relatively similar to *P. cleophanes*. Both have the head, mesosoma and petiole deeply rugose. *Polyrhachis salebrosa* is generally larger (HL 2.06-2.12 versus 1.84-1.96 in *P. cleophanes*) and has the dorsum of petiole transversely convex between distinctly elevated, shorter spines. In contrast, the dorsum of the petiole in *P. cleophanes* is almost flat, with the spines distinctly longer and more-or-less horizontal. The pronotal and propodeal spines in *P. cleophanes* are also distinctly longer and the gastral pubescence is much finer, more appressed and tidy, forming

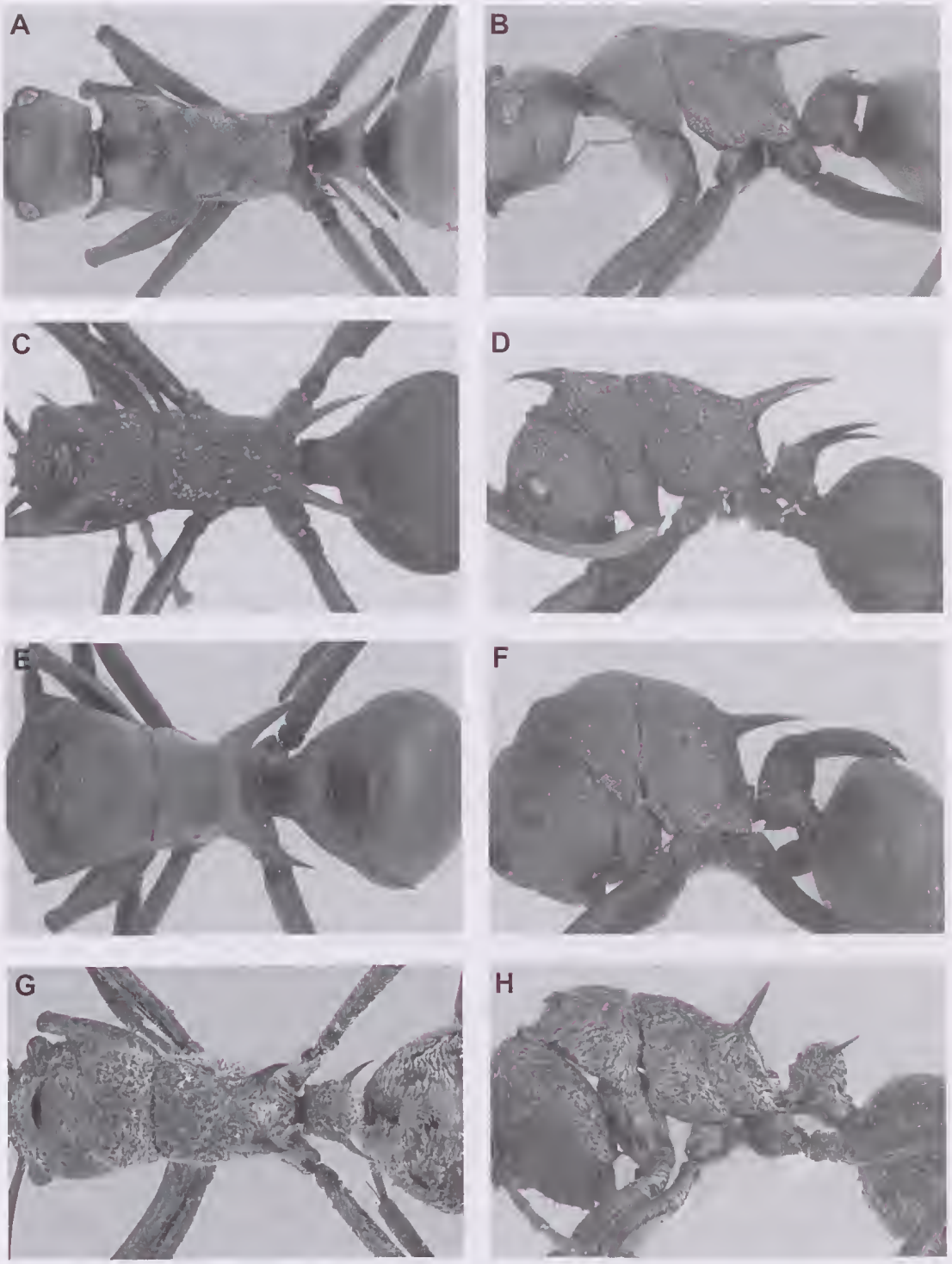

FIG. 8. *Polyrhachis* (Myrmhopla) species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B – *P. aberrans* sp. nov.; C-D – *P. armata* (Le Guillou); E-F, *P. strictifrons* Emery; G-H, *P. salebrosa* sp. nov. (not to scale).

a clearly defined median line, similar to that in *sexspinosa*-group species.

62. Polyrhachis smithi Emery, 1901

Polyrhachis smithi Emery, 1901: 579. Holotype worker. Type locality: INDONESIA, SULAWESI ('Gipfel des Sudara') (P. & F. Sarasin), ?MCSN (depository of holotype unknown).

REMARKS. I have been unable to examine the unique holotype of *P. smithi*, but it is apparently most similar to *P. cleophanes* and *P. salebrosa*. It differs from both in having the mesosoma somewhat flattened, the sculpturation of mesosomal dorsum transversally wrinkled and by the almost complete lack of erect hairs (Dorow, 1995).

Polyrhachis cryptoceroides species-group

63. Polyrhachis cryptoceroides Emery, 1887 (FIG. 9A-B)

Polyrhachis cryptoceroides Emery, 1887: 228, pl. 3, fig. 14. Syntype workers. Type locality: INDONESIA, SULAWESI, Macassar (O. Beccari), MCSN (examined).

Polyrhachis (Aulacomyrma) mystica Karawajew, 1927: 41, fig. 19. Syntype workers, queens, males. Type locality: INDONESIA, JAVA, Buitenzorg (= Bogor) (W. Karawajew), IZAS, QM (examined). Synonymy by Dorow, 1995: 51.

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 25.ii.1985 (N.E. Stork et al.) (w); ditto, 230m, 10.iii.1985, fog. (N.E. Stork et al.) (w); ditto, 11.vii.1985, fog. (N.E. Stork et al.) (w); ditto, Maze Toraut Riv., 00°34'N, 123°54'E, c. 220m, 1.-9.xi.1985 (Malaise trap) (C.van Achterberg) (w).

REMARKS. Direct comparison of Dumoga-Bone specimens with the syntype workers of *P. cryptoceroides* and *P. mystica* shows them undoubtedly conspecific. The *cryptoceroides*-group was recently reviewed by Kohout (2006a).

Polyrhachis dives species-group

64. Polyrhachis dives Fr. Smith, 1857

Polyrhachis dives Fr. Smith, 1857: 64. Holotype worker. Type locality: SINGAPORE (A.R. Wallace), BMNH (examined).

Polyrhachis mutiliae Fr. Smith, 1861: 39, pl. 1, figs 15, 20. Holotype worker. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined). Synonymy by Bolton, 1974: 173.

Polyrhachis democles Fr. Smith, 1861: 40, pl. 1, fig. 9. Holotype queen. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined) Synonymy by Forel, 1911: 298.

(For full synonymy citations see Bolton, 1974: 173 and 1995: 347).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP., Tumpah R., 7.x.1985 (Bosmans & Van Stalle #004) (w). SULAWESI TENGAH: Lore Lindu NP, nr Dongi-Dongi shelter, 01°15'S, 120°20'E, c. 975m, 4.xii.1985 (C.van Achterberg) (w); ditto, c. 1020m, 4.-9.xii.1985 (Malaise trap) (C.van Achterberg) (w, ♀).

REMARKS. *Polyrhachis dives* is a widespread species with a range that exceeds even that of *P. bicolor*. However, *P. dives* is less variable than the latter species, with specimens from South East Asia very similar to those from New Guinea and Northern Australia.

Polyrhachis flavoflagellata species-group

65. Polyrhachis storki sp. nov. (FIG. 9C-D)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Dumoga-Bone NP, 25.ii.1985, mangrove fog., N.E. Stork et al. (worker). PARATYPES: data as for holotype (1 worker). SULAWESI TENGAH: Lore Lindu NP, Toro, Watu Bohe, 860m, 14.iv.2005, cacao agrof., M.M. Bos #34 (1 worker). EAST MALAYSIA, SABAH: Kinabalu Park, Poring, c. 600m, vii.1991, M. Dill (1 worker). WEST MALAYSIA: Negara Sembilan, Pasoh FR, xi.1994, fog., M. Brendell, K. Jackson & S. Lewis (3 workers). Type deposition: Holotype and 1 paratype in BMNH, 1 paratype each in ANIC, FIS, MCZC and QM. ADDITIONAL MATERIAL. EAST MALAYSIA, SABAH: Forest Camp, 19km N of Kalabakan, 60m, 25.x.1962 (K.J. Kuncheria) (w).

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 6.85, 6.40-7.00; HL 1.72, 1.65-1.75; HW 1.53, 1.47-1.56; CI 89, 89-91; SL 1.72, 1.68-1.81; SI 112, 112-117; PW 1.12, 1.06-1.15; MTL 2.18, 2.12-2.31 (6 measured).

Anterior clypeal margin produced medially into a bilobed, deeply emarginate prominence. Clypeus with blunt, weakly indicated median carina; clypeus in profile very weakly sinuate, shallowly impressed anteriorly, weakly elevated posteriorly with flat, clearly defined basal margin. Frontal triangle distinct. Frontal carinae sinuate, virtually flat, with very weakly raised margins; central area relatively wide, flat; frontal furrow indicated by break in sculpture. Sides of head in front of eyes distinctly converging anteriorly, almost straight, only weakly rounding into mandibular bases; behind eyes strongly rounding into virtually flat occipital margin. Eyes large, weakly convex, in full frontal view situated at posterolateral corners and distinctly breaking lateral cephalic outline. Ocelli lacking. Pronotal humeri armed with distinct, acute teeth. Mesosomal dorsum in profile with

distinct, but flat promesonotal suture; metanotal groove indistinct dorsally, weakly indicated laterally; mesonotal and propodeal dorsa almost flat, with poorly defined, blunt, lateral margins. Propodeum armed with pair of dorsoposteriorly directed spines; declivity short, oblique in profile. Petiolar dorsum armed with pair of dorsolaterally directed spines. Anterior face of first gastral segment relatively low with base weakly concave; anterodorsal margin widely rounded.

Mandibles finely, longitudinally striate with numerous piliferous pits. Head, mesosoma and petiole finely and closely reticulate-punctate with sculpturation along occipital margin and on propodeal dorsum somewhat tranversely reticulate, wrinkled. Antennal scapes, legs and gaster more finely reticulate-punctate.

Mandibular masticatory borders with several curved, pale golden hairs. Anterior clypeal margin with single, medium long seta medially and several shorter setae fringing margin laterally. Apex of antennal scapes with very few short hairs. Gaster with only few, short, erect hairs at margins of apical dorsal segments, with somewhat longer hairs lining segments on ventral surfaces. Pale golden, short, closely appressed pubescence in various densities over most body surfaces, notably on mesosoma, petiole and gaster, but nowhere so dense as to hide underlying sculpturation. Pubescence most diluted on head, where it is almost completely absent from clypeus, sides and frontal area, except some scattered, extremely short, appressed hairs raising from piliferous pits.

Colour. Generally dark brown-black with somewhat reddish-brown, almost metalic, hue. Mandibular teeth narrowly reddish-brown; condylae, extreme tip of apical funicular segments and tarsal claws yellowish-brown. Legs very dark reddish-brown with distal portion of front tibiae shade lighter.

Sexuals and immature stages unknown.

REMARKS. Like *P. flavoflagellata* Karawajew, 1927 itself, *P. storki* is a widespread but rare species. They are superficially very similar, but undoubtedly distinct. Distinguishing characters include the relative length of the antennal scapes (SI <117 in *P. storki* versus SI >122 in *P. flavoflagellata*) and the shape of the anterior clypeal margin. The clypeus of *Polyrhachis storki* has a bilobed, medially emarginate prominence, while the anterior clypeal margin in *P. flavoflagellata* is widely truncate with a minute median incision. *Polyrhachis storki* has a widely rounded petiolar dorsum that bears only a pair of lateral, very weakly elevated spines. In *P. flavoflagellata* the petiolar dorsum is rather narrow and bears a pair of dorsolaterally directed spines as well as a pair of distinct intercalary teeth.

Polyrhachis furcata species-group

66. **Polyrhachis rufipes** Fr. Smith, 1858 (FIG. 9E-F)

Polyrhachis rufipes Fr. Smith, 1858: 66, pl. 4, fig. 28. Holotype worker. Type locality: BORNEO, SARAWAK, BMNH (examined).

Polyrhachis exasperatus Fr. Smith, 1861: 41, pl. 1, fig. 16. Holotype worker. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined). Synonymy by Bolton, 1974: 178.

(For full synonymy citations see Bolton, 1974: 178 and 1995: 355).

MATERIAL. SULAWESI SELATAN, Cagar Alam Karaenta, Kabupaten Maros, c. 265-315m, iii.1996 (B. Gobin) (♀).

REMARKS. A single alate queen collected by Bruno Gobin closely matches type compared material (queen and workers) from Borneo.

Polyrhachis hector species-group

KEY TO *HECTOR*-GROUP SPECIES
(based on workers)

1. Smaller (HL <2.00); body very slender with disproportionally long ('spider-like') appendages ..... *muelleri* Forel

   Larger (HL >2.20) with appendages proportional to rest of body 2

2. Gaster opaque, reddish or black; propodeal spines more-or-less horizontal ..... *abdominalis* Fr. Smith

   Gaster highly polished, black with dark reddish hue; propodeal spines distinctly obliquely elevated .... *pressa* Mayr

67. **Polyrhachis abdominalis** Fr. Smith, 1858 (FIG. 9G-H)

Polyrhachis abdominalis Fr. Smith, 1858: 63. Holotype worker. Type locality: BURMA, BMNH (examined).

Polyrhachis phyllophillus Fr. Smith, 1860a: 69. Holotype worker. Type locality: INDONESIA, SULAWESI, Makassar (A.R. Wallace), OXUM (examined). Synonymy by Mayr, 1886: 367.

(For full synonymy citations see Dorow, 1995: 54.)

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 11.ii.1985 (N.E. Stork et al.) (w); ditto, 22.ii.1985 (N.E. Stork et al.) (w); ditto, 7.vi.1985 (N.E. Stork et al.) (w); ditto, 400m, 11.ii.1985, fog. (N.E. Stork et al.) (w); ditto, 230m, 10.iii.1985, fog. (N.E. Stork et al.) (w); ditto, 230m, 11.vii.1985, fog. (N.E. Stork et al.) (w, ♀); ditto, 400m, 19.vii.1985, fog. (N.E. Stork et al.) (w); ditto, 8.-18.ii.1993 (Maryati Mohamed) (w). SULAWESI TENGAH: Kebung Kopi nr Palu,

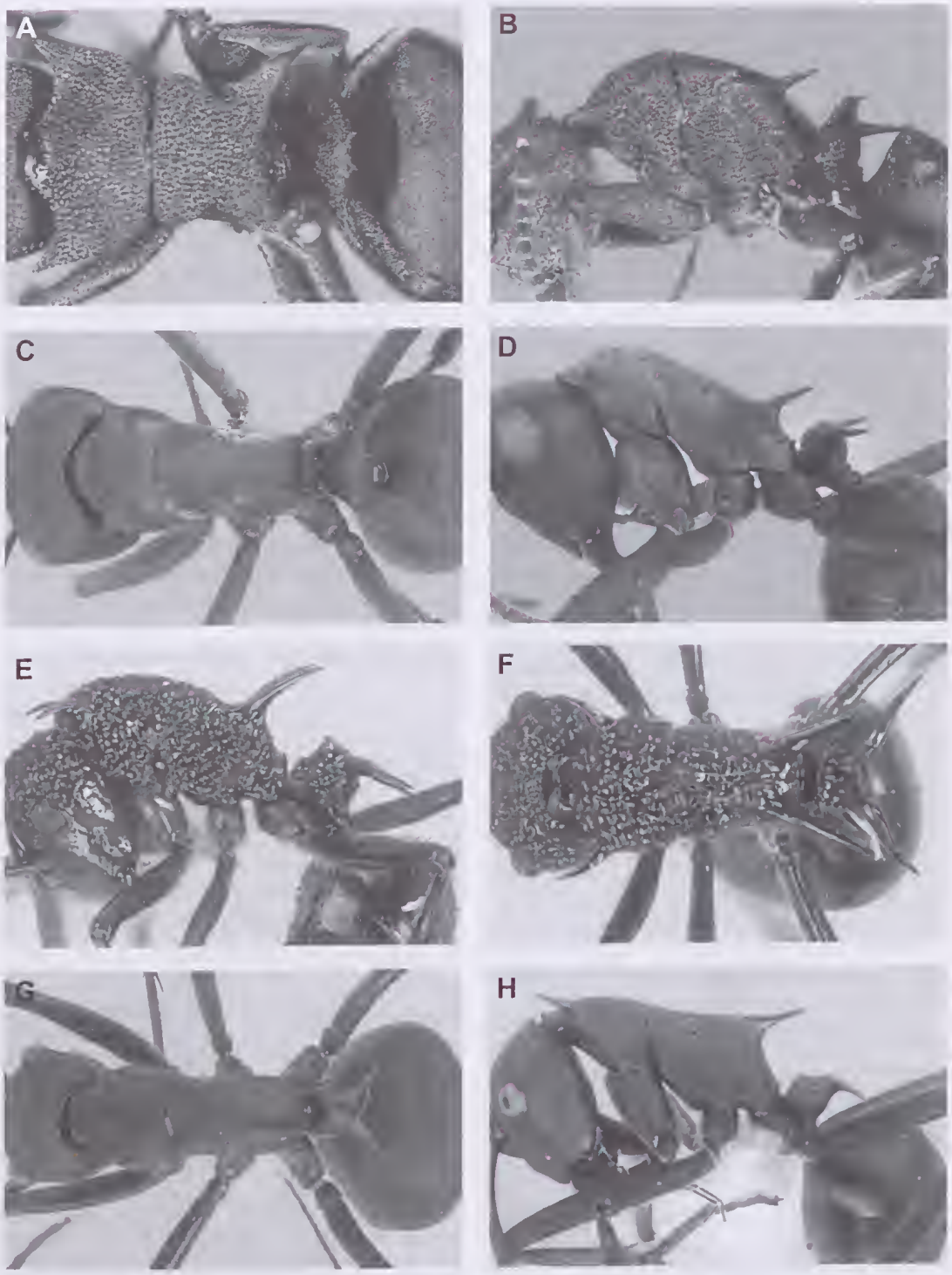

FIG. 9. *Polyrhachis* (Myrmhopla) species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. cryptoceroides* Emery; C-D, *P. storki* sp.nov.; E-F – *P. rufipes* Fr. Smith; G-H, *P. abdominalis* Fr. Smith (not to scale).

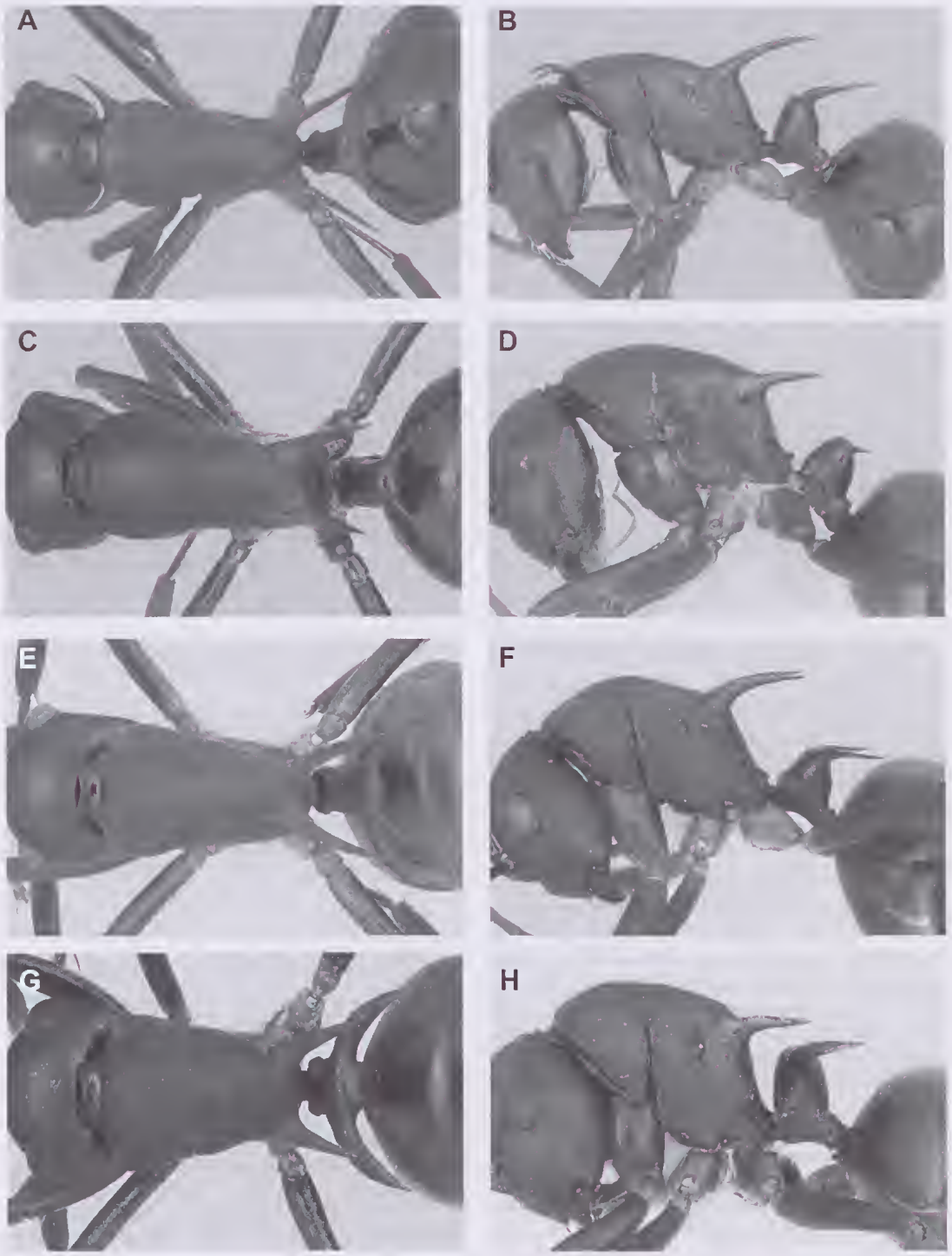

FIG. 10. *Polyrhachis* (Myrmhopla) species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. amana* Fr. Smith; C-D, *P. arborea* sp. nov.; E-F, *P. hippomanes* Fr. Smith; G-H, *P. manni* sp. nov. (not to scale).

16.viii.1992 (Sk. Yamane) (w); Lore Lindu NP, Toro, Baloli, 835m, 14.iv.2005, cacao agrof., fog. (M.M. Bos #1) (w); ditto, Toro, Bulu (Dusun Dua), 820m, 6.v.2005, cacao agrof., fog. (M.M. Bos #1) (w); ditto, Toro, Kaha, 920m, 15.iv.2005, cacao agrof., fog. (M.M. Bos #1) (w); ditto, Toro, Dusun Tuju, 815m, 3.v.2005, cacao agrof., fog. (M.M. Bos #1) (w); ditto, Toro, Watu Bohe, 860m, 14.iv.2005, cacao agrof., fog. (M.M. Bos #1) (w). SULAWESI SELATAN: Sampulage nr Mangktana, 02°16'S, 120°47'E, 1000m, 19.x.1999 (K. Ogata & K. Masaoka #69) (w).

REMARKS. Bolton (1974) synonymised *P. abdominalis* and *P. hector* Fr. Smith, however, Dorow (1995) considered them separate species. I have examined a vast number of specimens from across their distributions and am inclided to agree with Dorow's opinion. Specimens of *P. hector* feature a set of distinct, spur-like spines along the inner edge of the hind tibia, that are lacking in *P. abdominalis*. The latter species is also distinctly more slender.

68. Polyrhachis muelleri Forel, 1893

Polyrhachis muelleri Forel, 1893: 23, 32. Syntype workers. Type locality: SINGAPORE (A. Müller), MHNG (examined).

Polyrhachis muelleri Forel. Forel, 1901:302 (description of queen and male); Emery, 1925: 193 (combination in *P. (Myrmhopla)*).

(For full synonymy citations see Dorow, 1995: 55)

MATERIAL. SULAWESI TENGAH: Lore Lindu NP, Toro, Watu Bohe, 860m, 25.iv.2005 (cacao agrof.) (M.M. Bos #8) (w); ditto, Kauboga, 840m, 4.v.2005(cacao agrof.) (M.M. Bos #35) (w); ditto, Toro, Foot of Gn. Kamanua, 845m, 28.iv.2005 (cacao agrof.) (M.M. Bos #30) (♀); ditto, Toro, Bulu (Dusun Dua), 820m, 6.v.2005 (cacao agrof.) (M.M. Bos #36) (♀).

REMARKS. I have compared the Lore Lindu specimens with type-compared vouchers of *P. muelleri* from Malaysia and found them undoubtedly conspecific. *Polyrhachis muelleri* is a widespread species recorded from Thailand, Malaysia, Singapore, Borneo, Sumatra and Java. The biology of *P. muelleri* was described in detail by Dorow et al. (1990). The specimens collected by M.M. Bos are the first recorded from Sulawesi.

69. Polyrhachis pressa Mayr, 1862

Polyrhachis pressus Mayr, 1862: 681. Syntype workers, queen. Type locality: INDONESIA, JAVA, Batavia (= Jakarta) (Novara), NHMW (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 8.-18.ii.1993 (Maryati Mohamed) (w). SULAWESI TENGAH: Lore Lindu NP., Toro, Haloda, 815m, 21.iv.2005, cacao agrof., fog. (M.M. Bos #3) (w).

REMARKS. This is a very eharaeteristic, relatively rare species that is also known from Java and Borneo. It was reported from Sulawesi by Emery (1901: 569) but the workers from Lore Lindu and Dumoga-Bone National Parks are the only specimens I have seen from the island. The Sulawesian specimens are generally smaller than those from Java and Borneo (HL 2.15-2.46 versus HL 2.40-2.68) but they are otherwise identical and I consider them to represent an isolated population of *P. pressa*.

Polyrhachis mucronata species-group

KEY TO *MUCRONATA*-GROUP SPECIES (based on workers)

1. Pronotal humeri produced into slender, acute spines (Fig. 10A-B) ..... *amana* Fr. Smith

   Pronotal humeri angular or produced into broad-based short teeth (Fig. 10E, G) 2

2. Body with rather dense, closely appressed, silvery-white or greyish pubescence ..... *retrorsa* Emery

   Body jet-black with only very diluted appressed pubescence arising from minute shallow pits 3

3. Petiole with short lateral spines that are as long as, or shorter than distance between their bases (Fig. 10C); no intercalary spines present; pronotal humeri rounded, with or without indication of rudimentary teeth ..... *arborea* sp. nov.

   Petiole with relatively long lateral spines, conforming to shape of first gastral segment, and pair of intercalary teeth; pronotal humeri distinctly toothed (Fig. 10E, F) 4

4. Petiolar spines rather broad and massive (Fig. 10G); propodeal spines about as long as distance between their bases; generally black with coxae and proximal ends of femora distinctly light to medium reddish-brown ..... *mammi* sp. nov.

   Petiolar spines very slender (Fig. 10E); propodeal spines distinctly longer than distance between their closely approximate bases; generally black with legs dark reddish-brown; coxae a shade lighter ..... *hippomanes* Fr. Smith

70. Polyrhachis amana Fr. Smith, 1861 (FIG. 10A-B)

Polyrhachis amanus Fr. Smith, 1861: 41, pl. 1, fig 13. Syntype workers. Type locality: INDONESIA, SULAWESI, Tonadano (A.R. Wallace), OXUM, BMNH (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, Danau Mooat, 1100m, 31.vii.1985 (*Pandanus* fog.) (N.E. Stork et al.) (w). SULAWESI TENGAH: Lore Lindu NP, Toro, Kole Wuri, 1010m, 27.iv.2005, nat. for., fogging (M.M. Bos #25) (w). SULAWESI SELATAN: Mt Kaleakan, Tana Traja, 02°58'S, 119°54'E, 18.x.1999, 1000m (K. Ogata & K. Masaoka #63) (w).

REMARKS. The specimens from Dumoga-Bone are larger than the syntype examined (HL 1.90-2.00 versus HL 1.75 in a syntype) and differ in a number of characters. The clypeus in lateral view is distinctly sinuate in modern specimens, while in the syntypes it is virtually straight anteriorly and deeply impressed basally. The lateral outline of mesosoma of the modern specimens is moderately convex with its highest point located just behind the promesonotal suture. The mesosomal outline in the syntypes is more strongly convex with the highest point at the promesonotal suture itself. In the modern specimens the pronotal and propodeal spines are more divergent, the base of petiolar node in profile is broader and the petiolar spines are less elevated and almost straight. In the syntype the tips of the petiolar spines are slightly bent downwards. The colour of the body and appendages in modern specimens is uniformly black, with only the coxae and the proximal ends of femora reddish-brown. The body and most of the antennal scapes of the syntype are black, with the legs and antennal funiculi generally light to medium yellowish-brown. In spite of these differences I consider the modern material and syntype conspecific.

71. **Polyrhachis arborea** sp. nov. (FIG. 10C-D)

MATERIAL. HOLOTYPE: SULAWESI TENGAH: nr Morowali, Ranu R. area, 27.i.-20.iv.1980, M.J.D. Brendell, B.M. 1980-280 (worker). PARATYPES: data as for holotype (14 workers). SULAWESI UTARA: Dumoga-Bone NP, 9.-16.v. 1985 (N.E. Stork et al.) (worker); ditto, 230m, 2.xii.1985, fog., N.E. Stork et al. (worker). Type deposition: Holotype and (8) paratypes in BMNH; 2 paratypes each in ANIC, MCZC and QM.

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 6.25, 5.90-6.70; HL 1.59, 1.47-1.68; HW 1.22, 1.12-1.25; CI 77, 73-77; SL 2.09, 1.96-2.18; SI 171, 171-182; PW 0.87, 0.84-0.97; MTL 2.25, 2.09-2.34 (17 measured).

Anterior clypeal margin with median truncation, flanked by distinct, blunt denticles. Clypeus with blunt median carina that is weakly elevated posteriorly; clypeus in profile straight, rounding posteriorly into moderately impressed basal margin, laterally basal margin consisting of a thin, sculpture-breaking line. Frontal triangle distinct. Frontal carinae sinuate with distinctly raised margins; central area concave with rather short frontal furrow. Sides of head in front of eyes converging towards mandibular bases in weakly convex line; behind eyes sides rounding into relatively narrow, convex occipital margin. Eyes convex, in full face view clearly breaking lateral cephalic outline. Ocelli lacking. Pronotal humeri produced into blunt angles, rather indistinctly in some specimens. Mesosoma in profile with pronotal dorsum weakly convex; promesosonal suture distinct; mesonotal dorsum flat. Metanotal groove a distinct, posteriorly bowed line. Propodeal dorsum very short, with lateral margins terminating in broad-based, horizontal, weakly laterally and posteriorly directed spines; inner margins of spines curving onto propodeal dorsum, forming weakly open 'U' in dorsal view; declivity relatively high, oblique in profile. Petiole with pair of widely diverging, relatively short spines; petiolar dorsum rounded in profile, spines arising from below summit. Anterior face of first gastral segment widely rounding onto dorsum.

Mandibles finely, longitudinally striate, with numerous piliferous pits. Head shallowly reticulate-punctate, more distinctly on vertex. Mesosoma sculpturation ranging from very dense punctatation overlying larger, rather shallow depressions in some specimens to simply reticulate-punctate in others; general appearance ranging from opaque to moderately smooth and polished. Gaster finely shagreened.

Mandibular masticatory borders with several curved, golden hairs and numerous short, closely appressed hairs towards bases. Anterior clypeal margin with a few longer setae medially and a pair of rather short hairs arising laterally behing margin. Anterior face of fore coxae with one or two longer, erect hairs. Gaster with several medium length, erect hairs along dorsoapical margins segments; hairs more numerous and distinctly longer on gastral venter. Closely appressed, very short, golden pubescence arising from numerous pits over all body surfaces.

Colour. Head, mesosoma, petiole and mid and hind coxae black. Mandibles, clypeus and front of head blotched with diffuse reddish-brown. Antennae, legs and gaster medium reddish-brown with tarsi distinctly darker. Narrow band across bases of mandibular teeth, condylae, funicular segments towards apex and apical segment of tarsi, light yellowish-brown.

Sexuals and immature stages unknown.

REMARKS. The body sculpturation of *P. arborea* is rather variable. In most specimens of type series it consists of small punctures that are superimposed over larger, very shallow depressions. However, in the specimens from Lore Lindu the sculpturation

is simply reticulate-punctate. *Polyrhachis arborea* resembles *P. moesta* Emery and *P. orpheus* Forel. It differs from both in having considerably longer and more slender antennal scapes. The propodeal spines are also longer and virtually horizontal in *P. arborea*, while they are oblique in profile in the other two species.

72. Polyrhachis hippomanes Fr. Smith, 1861 (FIG. 10E-F)

Polyrhachis hippomanes Fr. Smith, 1861: 43, pl. 1, fig. 21. Holotype worker. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, Danau Mooat, 1100m, 31.vii.1985, *Pandanus* fog., (N.E. Stork et al.) (w). SULAWESI SELATAN: Sampulage nr Mangktana, 02°16'S, 120°47'E, 1000m, 19.x.1999 (K. Ogata & K. Masaoka #69) (w); ditto, 02°20'S, 120°48'E, 800m, 19.x.1999 (K. Ogata & K. Masaoka #73) (w).

REMARKS. Both specimens of *P. hippomanes* from Dumoga-Bone are very similar to the holotype but differ slightly in the colour of their legs. In the holotype they are uniformly dark brown, apart from the trochanters and proximal ends of femora that are a shade lighter. In the modern specimens the coxae, trochanters and the proximal halves of the femora are distinctly light reddish-brown. The propodeal and petiolar spines are also more widely divergent in the modern specimens. However, in all other aspects both match the *P. hippomanes* holotype and I am confident they are conspecific.

73. Polyrhachis manni sp. nov. (FIG. 10G-H)

MATERIAL. HOLOTYPE: SULAWESI SELATAN: Karaentha, 05°0.2S, 119°44'E, 270m, K. Ogata & K. Masaoka #99 (worker). PARATYPES: data as for holotype (worker); SE of Laduladu, 02°33'S, 121°22'E, 230m, 21.x.1999, K. Ogata & K. Masaoka #95 (worker); Bantimoerong (= Bantimurung), 1937, W.M. Mann, NGS SI Exp. (3 workers). SULAWESI UTARA: Dumoga-Bone NP, Rentiee II, 280m, 1-24. xi.1985, malaise trap (Bosmans & Van Stalle #106) (worker). Type deposition: Holotype (QMT144152) and 1 paratype in QM; 1 paratype each in ANIC, BMNH, IRSN, MCZC and NMNH. ADDITIONAL MATERIAL, SULAWESI TENGAH: Lore Lindu NP, Toro, Taiti, 840m, 26.iv.2005, cacao agrof., fog. (M.M. Bos #13a) (♀).

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 5.19, 5.04-5.49; HL 1.40, 1.33-1.40; HW 1.20, 1.12-1.20; CI 86, 84-86; SL 1.65, 1.56-1.65; SI 137, 137-145; PW 0.94, 0.87-1.00; MTL 1.68, 1.65-1.78 (6 measured).

Anterior clypeal margin with rather shallow, medially notched, rectangular flange, flanked by acute denticles. Clypeus with blunt median carina that is indistinct anteriorly; clypeus in profile convex, posteriorly rounding into weakly impressed basal margin, laterally basal margin indicated by thin, sculpture-breaking line. Frontal triangle shallowly impressed. Frontal carinae sinuate with raised margins; central area with weakly impressed frontal furrow. Sides of head in front of eyes convex, rounding into mandibular bases; behind eyes sides rounding into convex occipital margin. Eyes convex, in full face view breaking lateral cephalic outline. Ocelli lacking. Pronotal humeri armed with small, distinct teeth; lateral pronotal margins shallowly emarginate behind spines and rounded posteriorly. Promesonotal suture distinct; mesonotum rather strongly narrowed posteriorly; metanotal groove a distinct line, posteriorly bowed and weakly raised medially. Propodeal dorsum extremely short, with lateral margins forming outer edges of divergent, horizontal spines with their tips weakly bent downwards; declivity relatively high, very steep. Petiole with anterior face straight, posterior face convex; dorsum armed with a pair of horizontal curved spines that conform to the shape of gastral base in dorsal view and a pair of very short, acute, dorsoposteriorly directed, interealary teeth. Anterior face of first gastral segment with flat base and anterodorsal margin widely rounding onto dorsum.

Mandibles finely longitudinally striate with numerous piliferous pits. Head, mesosoma and petiole reticulate-punctate with sculpturation on meso- and metapleurae somewhat wrinkled. Gaster finely shagreened.

Mandibular masticatory borders and outer margins with numerous, relatively long, curved, golden hairs. Anterior clypeal margin with a few longer, anteriorly directed setae medially and several shorter setae fringing margin laterally. Two pairs of relatively short, erect hairs arising near anterior clypeal margin, one pair near basal margin and a few very short hairs fringing apex of antennal scapes. Posterior faces of fore coxae with several medium length, downward-directed hairs. Subpetiolar process anteriorly with tuft of short hairs. Gaster with only a few erect hairs lining apical segments dorsally; distinctly longer, more abundant hairs lining segments on venter. Extremely short, appressed, very diluted pubescence over most dorsal surfaces; pubescence on

gastral dorsum more abundant, but not so dense as to hide underlying sculpturation.

Colour. Black; mandibles, antennal scapes, fore coxae and tibiae medium reddish-brown with femora very dark reddish-brown. Small patch on mandibular masticatory borders, condylae, apical funicular segments, coxae of middle and hind legs and all trochanters very light yellowish-brown, with coxae blotched reddish-brown. Apical gastral segments, notably on ventral aspect, diffusely reddish-brown.

Queen. Dimensions: TL c. 7.21; HL 1.62; HW 1.34; CI 83; SL 1.87; SI 139; PW 1.53; MTL 2.09 (1 measured).

Very similar to worker but larger and with usual differences indicating caste, including three ocelli and complete thoracic structure. Pronotal humeri armed with distinct teeth; mesoscutum almost as long as wide, with anterior face and dorsum forming a continuous, weakly convex line in lateral view; mesoscutellum convex. Propodeal dorsum short, descending into oblique declivity in medially uninterrupted line; spines broad-based, about twice as long as their basal widths. Petiole similar to that in worker with spines distinctly shorter. Sculpturation of body, pilosity and colour virtually as in worker.

Males and immature stages unknown.

REMARKS. *Polyrhachis uanni* is undoubtedly closely related to *P. lucidula* Emery and to *P. ridleyi* Forel. In addition to their similar general appearance, they all have rather broad petiolar spines. However, the spines in *P. uanni* are distinctly less massive than in the other two species and the dorsum of the petiole bears two short, acute, intercalary spines that are lacking in both *P. lucidula* and *P. ridleyi*. For additional notes on the latter two species see Kohout (1998: 516).

74. Polyrhachis retrorsa Emery, 1900

Polyrhachis retrorsa Emery, 1900: 719. Syntype worker, queens. Type locality: INDONESIA, Mentawei I., Sipora, Sereinu (E. Modigliani), MCSN (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, 400m, 11.ii.1985, fog., (N.E. Stork et al.) (w); ditto, 9.-16.v.1985 (N.E. Stork et al.) (w); ditto, 19.vii.1985, fog., (N.E. Stork et al.) (w). SULAWESI TENGAH: Lore Lindu NP, Gn. Kamonua, 1080m, 20.iv.2005, nat. for., fog. (M.M. Bos #42) (w). SULAWESI TENGGARA: 1-2km E of Wolasi, 42km S of Kendari, c. 350m, rf, 13-14.vii.1972 (W.L. Brown) (w).

REMARKS. *Polyrhachis retrorsa* bears a very close resemblance to *P. mitrata* Menozzi from the Philippines but direct comparison of the types of both species supports their separate specific status. *Polyrhachis mitrata* has a narrower mesosoma with the pronotal humeri angular and the propodeal and petiolar spines distinctly more slender. The petiole in lateral view has a weakly convex anterior face, an almost straight posterior face and a rather narrow dorsum that bears a pair of minute, posteriorly directed, intercalary teeth. *Polyrhachis mitrata* is black with the legs and gaster medium reddish-brown and the antennae a shade darker and the body is covered with whitish pubescence that is rather diluted, notably on dorsum of the head, mesosoma and gaster. However, the syntype examined appears to be a worn specimen. In contrast, the pronotal humeri in *P. retrorsa* are unarmed and widely rounded and the propodeal spines shorter and broader at their bases. In profile, both faces of the petiole are convex and only slightly converge towards the widely rounded dorsum. The petiole generally lacks intercalary teeth, although rudimentary teeth are evident beneath the pubescence in a few specimens. *Polyrhachis retrosa* is black with reddish-brown appendages and has relatively long, appressed, silvery-grey pubescence that clearly distinguishes the species from the other, mostly jet black members of the *mucronata*-group.

Polyrhachis sexspinosa species-group

KEY TO *SEXSPINOSA*-GROUP SPECIES (based on workers)

1. Pronotal spines short, straight, directed laterally in virtually right angle to main axis of body . . *rugifrons* Fr. Smith

   Pronotal spines bull-horn shaped, curving laterally and anteriorly . . . . . *spinosa* Mayr

75. Polyrhachis rugifrons Fr. Smith, 1860

Polyrhachis rugifrons Fr. Smith, 1860a: 70. Syntype worker, queen. Type locality: INDONESIA, SULAWESI, Makassar (A.R. Wallace), OXUM (examined).

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, Tumpah R., mid vi.-4.vii.1985, for. edge (C.van Achtenberg) (w); SULAWESI TENGAH: Lore Lindu NP, Toro, Gn. Kalabui, 950m, 16.iv.2005, nat. for., fog. (M.M. Bos #39) (w); ditto, Toro, Kaha, 920m, 15.iv.2005, cacao agrof., fog. (M.M. Bos #39) (w, ♀); ditto, Toto, Gn. Kamonua, 1080m, 20.iv.2005, nat. for., fog. (M.M. Bos #39) (♀); SULAWESI TENGGARA: Wolasi, Pangalulu, 04°10'S, 122°30'E, 140m, 13.x.1999 (K. Ogata & K. Masaoka #46) (w). SULAWESI SELATAN: Gn. Bulusaraung, nr Camba Malawa, c. 750m, 7.ii.-28.iii.1995 (Malaise trap) (C.van

Achterberg & Y. Yasir) (w); Bantimurung, Ujung Pandang, 8.viii.1992 (Sk. Yamane) (w); Bantimoerong (= Bantimurung), 1937 (W.M. Mann, NGS SI Exp.) (w).

REMARKS. The syntype worker of *P. rugifrons* compares well with the specimens listed above. *Polyrhachis rugifrons* and *P. spinosa* Mayr, listed below, appear to be the only representatives of the *sexspinosa*-group in Sulawesi. However, while the distribution of *P. spinosa* is centered on Halmahera, with only a few collections known from elsewhere (Morotai I.), *P. rugifrons* appears to be endemic to Sulawesi.

76. Polyrhachis spinosa Mayr, 1867 **stat. rev.**

Polyrhachis spinosa Mayr, 1867:43, pl. 2, fig.2. Syntype worker, queen. Type locality: INDONESIA, HALMAHERA, Dodinga (Forsten), RMNH (examined).

Polyrhachis spinosa Mayr. Bolton, 1975: 6. (considered a junior synonym of *P. bubastes* Fr. Smith).

MATERIAL. INDONESIA, SULAWESI: (as Celebes) in copal, (Franklin Müller) (w) (DEIE).

REMARKS. A single specimen from copal appears to be the only record of this species from Sulawesi. *Polyrhachis spinosa* is known from Halmahera and Morty I. (= Morotai I. in Maluku Utara). Bolton (1975) synonymised *P. spinosa* with *P. bubastes* and assumed that the types of the former had been lost. However, I have discovered the *P. spinosa* syntypes (worker and queen) in the RMNH collection and following their comparation with the *P. bubastes* types (OXUM), I am confident that they represent separate species. In his original description, Mayr (1867) illustrated both castes and listed characters separating *P. spinosa* from the closely allied species, *P. sexspinosa*, *P. rugifrons* and *P. bubastes*. Some of the more useful characters distinguishing this group of species are discussed below. The occipital margins of *P. sexspinosa* and *P. spinosa* feature lateral angular prominences or lobes that are clearly visible in full face view. These lobes are weakly developed and barely visible in *P. bubastes* and *P. rugifrons*. In profile, the pronotal dorsum is strongly swollen and dome-like in *P. bubastes* and *P. sexspinosa*, while it is only moderately convex in the other two species. The pronotal spines are strongly curved forwards in *P. sexspinosa*, *P. spinosa* and *P. bubastes*, but in *P. rugifrons* they are short, straight and project laterally, almost at right angles to the main axis of the body. A mesopleural tooth is strongly developed in *P. bubastes*, while it is a simple, non-dentiform lobe in *P. sexspinosa* and *P. rugifrons* and virtually absent in *P. spinosa*. Although the propodeal spines are variable in length and degree of elevation in *P. sexspinosa*, they are generally long and vertical to the main axis of the body, or even inclined anteriorly. The propodeal spines are curved backwards in the other species, but while they are long in *P. rugifrons* and *P. spinosa*, they are distinctly shorter in *P. bubastes*. The form of the petiolar spines varies considerably among the species. In *P. rugifrons* they are long and slender and embrace the base of first gastral segment. In *P. sexspinosa* they are long, slender, strongly elevated and weakly curved. The spines are short, slender, only weakly elevated, and divergent in *P. bubastes*, while they are long, relatively thick, strongly elevated and subparallel in *P. spinosa*. *Polyrhachis sexspinosa* and *P. rugifrons* have the body covered with mostly yellowish or off-white, rather dense pubescence, that almost completely or partly hides the underlying sculpturation respectively. In contrast, *P. bubastes* and *P. spinosa* have the body clothed with numerous, rusty brown or black, short, erect hairs that do not mask the underlying sculpturation.

Subgenus **Myrmothrinax** Forel, 1915

The subgenus *Myrmothrinax* has never been formally subdivided, but with the number of its constituent species rapidly increasing, I am proposing two species-groups, based on the most characteristic feature in the workers, the relative lengths of the petiolar spines. The *aequalis*-group includes species with the petiolar spines more-or-less subequal or with the middle spine shorter than the lateral pair. The *thrinax*-group includes those species with a distinctly elongated middle spine.

Polyrhachis javanica Mayr, a member of the *aequalis*-group, was reported from Sulawesi by Emery (1901, 1925) but I consider this record erroneous. Emery evidently based his record on specimens collected from Sulawesi by Fruhstorfer that were identified by Mayr. I have examined four of these specimens (MCZC) bearing original identification tags inscribed as follows: (1) specimen from Patunuang – "*Polyrhachis thrinax* Rog. v. *javan*. Mayr det. Mayr"; (2) specimen from Toli-Toli – "*Polyrhachis thrinax* Rog. det. Mayr", "var. *javana* Mayr det. Mayr"; (3) specimen from Toli-Toli: "*P. thrinax* Rog. v. *javanica* det. Mayr"; (4) specimen from Patunuang "*Polyrhachis thrinax* Rog. det. Mayr", "var. *javana* Mayr det. Mayr". Mayr described *P. thrinax javanica* in 1867 and about thirty years passed before the identifications of Fruhstorfer's specimens.

By then the unique holotype of *P. thrinax javanica* had been returned to its owners and Mayr evidently lacked any material for comparison. Consequently, the accuracy of his identifications was compromised and ultimately incorrect. Moreover, Fruhstorfer's specimens comprised two, superficially similar, but distinct species, both described below. Specimens (1) and (2) are *P. incognita* sp. nov., while specimens (3) and (4) are *P. deceptor* sp. nov..

Mayr (1867), in his orginal description, designated a holotype for *P. thrinax javanica*. However, there are two available specimens in NRMS that are undoubtedly from the original series. Of these, I consider the specimen bearing Mayr's identification tag to be the holotype. The holotype is pinned and in relatively good condition. It agrees with Mayr's short description of that species to the extent that "[...] petiolus nodiformis supra spinis 3 gracilibus, subaequilongis, erectis, Paulo postice directis et rectis" and further on "... wärend bei dem von mir untersuchten Exemplare der mittlere Dorn nur um Weniges länger ist als die seitlichen Dornen". However, Mayr failed to mention that the apex of the middle spine is shallowly emarginated. The second specimen, once apparently pinned, is fragmented with the pronotum missing and the head, mesonotum, propodeum, petiole, gaster and two legs glued separately onto a card. Both specimens are exceptionally small (HL 1.37) and do not match any of the recently examined *Myrmothrinax* specimens from Sulawesi. They each bear two identical locality labels inscribed 'Java' and '*Kmb.*', with the holotype also bearing Mayr's identification tag – "*P. thrinax* v. *javana* det. Mayr". It is surprising that Mayr frequently used '*javana*' (including on the holotype tag), instead of '*javanica*' as it was originally published. The incorrect spelling '*javana*' was also used by Emery (1887) and Forel (1893).

Polyrhachis aequalis species-group

KEY TO *AEQUALIS*-GROUP SPECIES (based on workers)

1. Pronotal humeri with distinct teeth or short spines (Fig. 12A) 2

   Pronotal humeri widely rounded, without teeth or spines; petiolar spines very short with middle spine shorter or rudimentary in some specimens (Fig. 12E) ..... *trispinosa* Fr. Smith

2. Body generally light reddish-brown, with appendages and gaster a shade darker ..... *deceptor* sp. nov.

   Body generally black, or dark reddish-brown, with appendages sometimes a shade lighter 3

3. Smaller species (HL <1.56); pronotal humeri produced into short teeth ..... *aequalis* Forel

   Larger species (HL >1.65); pronotal humeri produced into short, distinct spines 4

4. Body and appendages black; propodeal spines relatively short, wide-based, somewhat triangular in lateral view (Fig. 12D) ..... *incognita* sp. nov.

   Body very dark reddish-brown to black, appendages and gaster medium to dark reddish-brown; propodeal spines relatively long and slender (Fig. 12B).... *imitator* sp. nov.

77. Polyrhachis aequalis Forel, 1910

Polyrhachis textor var. *aequalis* Forel, 1910: 129. Syntype workers, queen. Original localities: PHILIPPINES, LUZON, Province of Zambales, Olongapo (C.S. Banks); NEGROS Occ., Maao (C.S. Banks), BSMP (types destroyed – see Balthasar, 1966: 284), MHNG, QM (examined).

Polyrhachis aequalis Forel. Kohout, 1998: 509.

MATERIAL. SULAWESI UTARA: Dumoga-Bone NP, nr Toraut bank cl., 00°34'N, 123°54'E, 10.-18. xi.1985 (C.van Achterberg) (w).

REMARKS. Two workers from Dumoga-Bone NP compare well with the *P. aequalis* syntypes and other available specimens of the species from the Philippines.

78. Polyrhachis deceptor sp. nov. (FIG. 11G-H)

MATERIAL. HOLOTYPE: SULAWESI UTARA: Dumoga-Bone NP, nr Danau Mooat, 1100m, 1.viii.1985, coffee fog., N.E. Stork et al. (worker). PARATYPES: data as for holotype (6 workers). Type deposition: Holotype and 2 paratypes in BMNH; 1 paratype each in ANIC, CASC, MCZC and QM. ADDITIONAL MATERIAL. SULAWESI TENGAH: Lore Lindu NP, Toro, Kaha, 920m, 15.iv.2005, cacao agrof., fog. (M.M. Bos #18, 19) (w, ♀); ditto, Toro, Baloli, 835m, 14.iv.2005, cacao agrof., fog. (M.M. Bos #2) (♀); ditto, Toro, Foot of Gn. Kamanua, 845m, 28.iv.2005, cacao agrof., fog. (M.M. Bos #20) (♀).

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 6.15, 6.10-6.75; HL 1.65, 1.59-1.75; HW 1.40, 1.34-1.50; CI 85, 84-86; SL 2.03, 1.93-2.18; SI 145, 141-150; PW 0.90, 0.84-1.00; MTL 2.21, 2.15-2.40 (7 measured).

Anterior clypeal margin with medial, widely and shallowly emarginate truncation, flanked by distinct teeth. Clypeus with blunt, posteriorly distinct median carina; clypeus very weakly convex in profile, abruptly rounding into rather shallow basal margin, laterally basal margin indicated by a thin, sculpture-breaking line. Frontal triangle indistinct. Frontal carinae sinuate with margins very narrowly, vertically raised; central area relatively wide, weakly convex medially, with shallow frontal furrow. Sides of

head in front of eyes weakly convex, converging towards mandibular bases; behind eyes sides broadly rounding into convex occipital margin. Eyes convex, in full face view clearly exceeding lateral cephalic outline. Ocelli lacking. Pronotal humeri armed with relatively long, laterally directed spines; outer edges of spines continuous with somewhat sinuate lateral pronotal margins. Promesonotal suture distinct. Mesonotum with lateral margins strongly converging and somewhat raised posteriorly, shallowly emarginate medially; dorsum in profile distinctly stepping down into metanotal groove. Propodeum rather flat with lateral margins terminating posteriorly in almost vertically elevated, gently curved, weakly divergent spines; propodeal dorsum descending into oblique declivity in medially uninterrupted line. Petiole with anterior face flat, posterior face convex; dorsum armed with three, rather long, acute, dorsoposteriorly directed, subequal spines, lateral pair distinctly diverging. Anterior face of first gastral segment widely rounding onto dorsum.

Mandibles very finely reticulate. Head, mesosoma and petiole reticulate-punctate; pronotal dorsum with weak, irregular but largely longitudinal striae that are bowed towards posterolateral pronotal angles. Dorsum of mesonotum and propodeum reticulate-rugose, with sides of mesosoma densely and regularly reticulate-punctate. Gaster finely shagreened.

Mandibular masticatory borders with only a few, curved, golden hairs and numerous very short hairs arising from pits towards bases. Anterior clypeal margin with several rather short setae. A few pairs of relatively short, erect hairs near anterior and basal clypeal margins, along frontal carinae and a single pair of slightly longer hairs on vertex. Anterior face of fore coxae with pair of erect hairs that are almost as long as greatest diameter of eye. Gaster with very short erect hairs on posterodorsal margins of apical segments; more abundant, longer hairs lining margins of segments on gastral venter. Very short, closely appressed, somewhat diluted, golden pubescence over most body surfaces; pubescence dense and pale on dorsum of first gastral segment, almost white towards sides.

Colour. Distinctly light reddish-brown, with clypeus, central area, condylae and most of last funicular segment lighter, yellow-orange. Vertex with dark reddish, diffuse patch medially. Mandibles, coxae and legs very dark, reddish-brown, with antennal scapes almost black. Anterior clypeal margin, frontal carinae, condylae, mandibular bases, border along pronotal collar and very narrow border along lateral margins of pronotum, mesonotum and propodeum, including spines, very dark reddish-brown. Dorsum of first gastral segment reddish-brown, distinctly more yellowish than head and mesosoma. Rest of gaster distinctly darker, reddish-brown with segments somewhat diffusely bordered with very dark reddish-brown.

Queen. Dimensions: TL c. 8.21-8.52; HL 1.96-2.00; HW 1.65-1.68; CI 84-86; SL 2.21-2.34; SI 134-139; PW 1.62-1.65; MTL 2.46-2.58 (3 measured).

Very similar to worker with usual differences indicating caste, including three ocelli and complete thoracic structure. Pronotal humeri produced into blunt teeth; mesoscutum with lateral margins converging anteriorly towards rather narrowly rounded anterior margin; median line distinct, bifurcate; parapsides flat; mesoscutellum moderately elevated above dorsal plane of mesoscutum. Propodeum armed with somewhat dorsally flattened, weakly divergent, upturned spines; petiolar spines more massive and shorter than in worker, with median spine marginally shorter than lateral pair. Dorsum of mesoscutum and mesoscutellum with numerous, moderately long, semierect hairs that are completely absent in workers. Sculpturation and colour virtually as in worker.

Males and immature stages unknown.

REMARKS. *Polyrhachis. deceptor* is similar to *P. abnormis* Donisthorpe from New Guinea, and to several undescribed species of the subgenus from Borneo. *Polyrhachis deceptor* and *P. abnormis* have the pronotal dorsum irregularly, but mostly longitudinally striate, elongated pronotal spines that are longer than their basal widths, strongly elevated propodeal spines and subequal petiolar spines. *Polyrhachis deceptor* differs from *P. abnormis* in having shorter, horizontal and more laterally directed pronotal spines and gently curved, distinctly divergent propodeal spines. The pronotal spines in *P. abnormis* are distinctly elevated and anterolaterally directed and the propodeal spines are very slender, almost vertical and parallel. The overall colour pattern of both species is similar, yellowish- or light reddish-brown, but the appendages in *P. abnormis* are concolourous with the rest of the body, while they are dark to very dark brown in *P. deceptor*. The specimens of *P. abnormis* from Lore Lindu differ in colour from those from Dumoga-Bone. The type

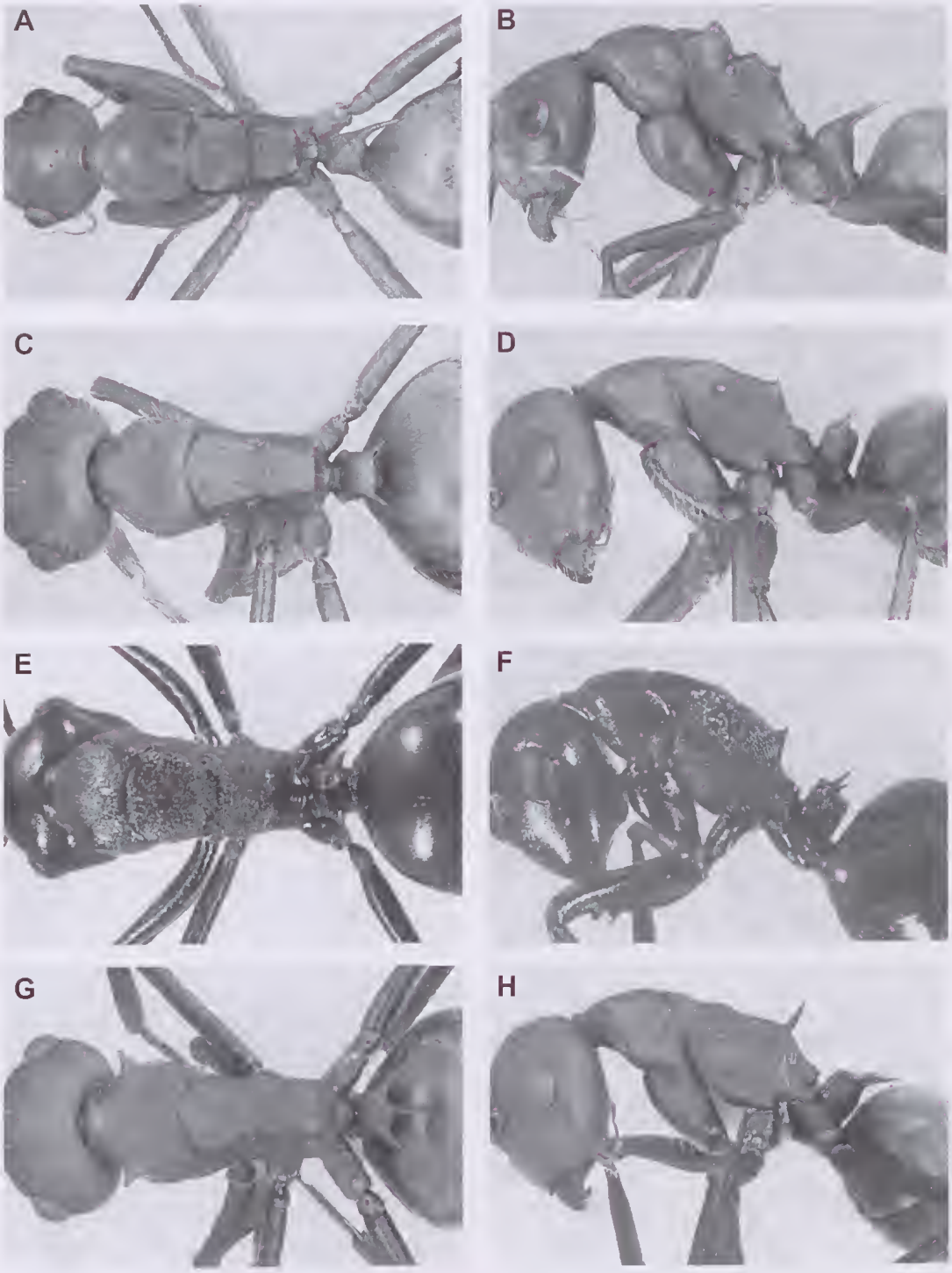

FIG. 11. *Polyrhachis* (*Myrmatopa* & *Myrmothrinax*) species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. mellita* sp. nov.; C-D, *P. hispida* sp. nov.; E-F, *P. kazuoi* sp. nov.; G-H, *P. deceptor* sp. nov. (not to scale).

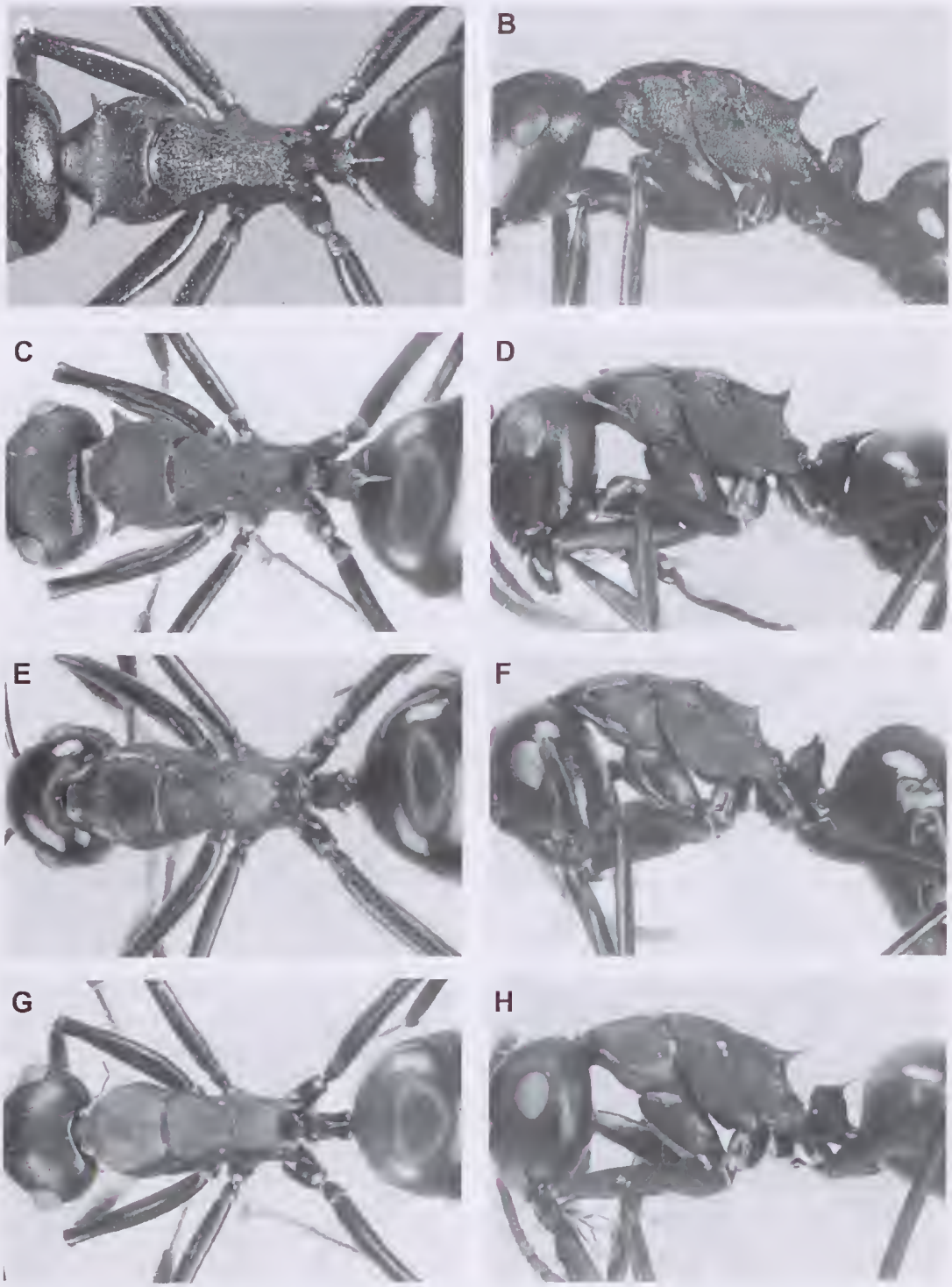

FIG. 12. *Polyrhachis* (Myrmothrinax) species, Dorsal (left) and lateral (right) view of mesosoma and petiole: A-B, *P. imitator* sp. nov.; C-D, *P. incognita* sp. nov.; E,-F, *P. trispinosa* Fr. Smith; G-H, *P. unicuspis* Emery (not to scale).

series specimens are distinctly reddish-brown, while those from Lore Lindu are yellowish-brown without a reddish hue. However, they are virtually identical morphologically and I consider them conspecific.

79. **Polyrhachis imitator** sp. nov.
(FIG. 12A-B)

MATERIAL. HOLOTYPE: SULAWESI TENGAH, Lore Lindu NP, Toro, Haloda, 815m, 17.iv.2005, cacao fog., M.M. Bos (worker). PARATYPES: data as for holotype (10 workers, 1 queen). Type distribution: Holotype worker (QMT144153), 2 paratype workers and paratype queen in QM; 2 paratype workers each in ANIC, BMNH, GUGG (Bos coll.) and MCZC.

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 6.55, 6.50-7.21; HL 1.68, 1.65-1.72; HW 1.47, 1.43-1.53; CI 87, 87-91; SL 1.96, 1.93-1.98; SI 133, 128-137; PW 0.94, 0.90-1.00; MTL 2.18, 2.12-2.25 (11 measured).

Anterior clypeal margin medially with wide, relatively shallow, 'V'- shaped emargination, flanked by distinct teeth. Clypeus with short median carina; convex in profile, rounding into deeply impressed basal margin, laterally basal margin indicated by thin, sculpture-breaking line. Frontal triangle weakly indicated. Frontal carinae sinuate with narrowly raised margins; central area relatively wide with weakly impressed frontal furrow. Sides of head in front of eyes converging towards mandibular bases in almost straight line; behind eyes sides widely rounding into weakly convex occipital margin. Eyes convex, in full face view clearly exceeding lateral cephalic outline. Ocelli lacking; relative positions of lateral ocelli indicated by shallow punctures. Pronotal dorsum weakly convex in profile; humeri with spines marginally longer than their basal widths; outer margins of spines continuous with posteriorly converging lateral pronotal margins. Promesonotal suture distinct; mesonotal dorsum weakly concave between slightly raised, posteriorly converging lateral margins. Propodeal dorsum with lateral margins parallel, terminating posteriorly in relatively long, slender, virtually parallel, dorsoposteriorly directed spines; propodeal dorsum descending into oblique declivity in medially uninterrupted line. Petiole with anterior face straight, posterior face convex; dorsum armed with three, slender, subequal spines; apex of median spine weakly upturned and shallowly emarginate (in holotype and some paratypes) or pointed; lateral spines weakly curved posterolaterally from their bases. Anterior face of first gastral segment flat, widely rounding onto dorsum.

Mandibles very finely, mostly longitudinally rugose with numerous shallow pits. Clypeus finely striate-punctate. Head and mesosoma reticulate-punctate; pronotal dorsum with somewhat irregular, longitudinal, posteriorly bowed rugae. Sides of mesosoma and petiole distinctly reticulate. Gaster finely shagreened.

Mandibles with a few, moderately long, subcrect, golden hairs at masticatory borders and extremely short, closely appressed hairs towards their bases. Anterior clypeal margin with a few longer setae medially and fringe of a few, short setae laterally. A few pairs of short, erect hairs near anterior and basal clypeal margins, along frontal carinae and a single pair on vertex. Anterior, posterior and ventral faces of fore coxae with a few, relatively long hairs; mid and hind coxae with a few shorter, erect hairs ventrally. Femora and trochanters each with a single, medium length, erect hair on ventral surfaces. Gaster with a few shorter erect hairs along apical segments dorsally; hairs longer and more abundant on gastral venter. Very short, appressed, mostly white pubescence on dorsum of gaster; pubescence virtually absent from rest of dorsal body surfaces.

Colour. Dark reddish-brown, with mandibles, clypeus, coxae, most of legs and gaster medium reddish-brown; condylae, apical segments of funiculi and mandibular masticatory borders, light yellowish-brown.

Queen. Dimensions: TL c. 9.78; HL 2.25; HW 1.90; CI 84; SL 2.40; SI 126; PW 1.84; MTL 2.93 (1 measured).

Apart from sexual characters and larger size, closely resembling worker except: pronotal humeri armed with blunt teeth; mesoscutum with virtually flat dorsum and lateral margins converging anteriorly towards rather narrowly rounded anterior margin; median line distinct, parapsides flat; mesoscutellum marginally elevated above dorsal plane of mesoscutum. Propodeum armed with strong, somewhat dorsally flattened, obliquely directed spines; petiolar spines shorter than in worker, median spine marginally shorter than lateral spines. Sculpturation and colour virtually as in worker.

Males and immature stages unknown.

REMARKS. *Polyrhachis imitator* is very similar to *P. incognita* described below, with

the main distingushing characters listed in the remarks section of the latter. It also bears some resemblance to *P. aequalis* from the Philippines and newly recorded from Sulawesi above. However, *P. imitator* is larger (HL >1.65 versus <1.56 in *P. aequalis*) and has well developed pronotal spines that are reduced to short teeth in *P. aequalis*.

80. Polyrhachis incognita sp. nov. (FIG. 12C-D)

MATERIAL. HOLOTYPE: SULAWESI TENGAH, Lore Lindu NP, Toro, Powawua, 810m, 18.iv.2005, cacao fog., M.M. Bos (worker). PARATYPES: data as for holotype (2 workers, 1 queen). SULAWESI UTARA, Dumoga-Bone NP, Tumpah R., 7.x.1985, Bosmans & Van Stalle #004) (1 worker). Type deposition: Holotype worker (QMT144154) and paratype queen in QM; 1 paratype worker each in GUGG (Bos coll.), IRSN and MCZC. ADDITIONAL MATERIAL. SULAWESI SELATAN (as S. Celebes on locality label): Patunuang, i.1896, H. Fruhstorfer (worker). PARATYPE: SULAWESI TENGAH (as Nord-Celebes on locality label): Toli-Toli, xi.-xii.1895, H. Fruhstorfer (worker).

DESCRIPTION. *Worker*. Dimensions (holotype cited first): TL c. 6.80, 6.65-7.61; HL 1.75, 1.68-1.75; HW 1.53, 1.47-1.53; CI 87, 87; SL 2.12, 2.03-2.21; SI 138, 138-147; PW 1.06, 1.00-1.06; MTL 2.34, 2.18-2.53 (4 measured).

Anterior clypeal margin medially with wide, deep, 'V'-shaped emargination, flanked by rather blunt teeth. Clypeus with short median carina; clypeus weakly convex in profile, rounding into deeply impressed basal margin, laterally basal margin indicated by thin, sculpture-breaking line. Frontal triangle weakly indicated. Frontal carinae sinuate with narrowly raised margins; central area relatively wide with poorly indicated frontal furrow. Sides of head in front of eyes converging towards mandibular bases in almost straight line; behind eyes sides widely rounding into weakly convex occipital margin. Eyes convex, in full face view clearly exceeding lateral cephalic outline. Ocelli lacking. Pronotal dorsum flat; humeri with spines distinctly longer than their basal widths, directed anterolaterally and weakly downward; outer margins of spines merging with posteriorly converging, lateral pronotal margins. Promesonotal suture distinct; mesonotal dorsum weakly concave in profile; lateral mesonotal margins distinctly raised and strongly converging towards distinct metanotal groove. Propodeal dorsum relatively narrow with lateral margins parallel, terminating posteriorly in rather short, broad-based, upturned spines; propodeal dorsum descending into oblique declivity in medially uninterrupted line. Petiole with anterior face straight, posterior face convex; dorsum armed with three, broad-based, subequal spines; lateral pair weakly curved posterolaterally from their bases. Anterior face of first gastral segment flat, widely rounding onto dorsum.

Mandibles very finely striate with numerous shallow pits. Clypeus finely, anteromedially striate-punctate. Sides of head and vertex reticulate-punctate with sculpture in front of eyes mostly longitudinally directed. Pronotal and mesonotal dorsa longitudinally striate-punctate with striae on pronotum bowed towards posterior corners. Sides of mesosoma reticulate-punctate with petiole distinctly punctate-rugose. Gaster finely shagreened.

Mandibles with a few, short, mostly erect, golden hairs at masticatory borders and extremely short, closely appressed hairs towards bases. Anterior clypeal margin with a few longer setae medially and fringe of short setae laterally. A few pairs of short, erect hairs near anterior and basal clypeal margins, along frontal carinae and a single pair on vertex. Anterior, posterior and ventral faces of fore coxae with a few, relatively long, somewhat curved hairs; mid and hind coxae with a few shorter erect hairs ventrally. Femora with a few, medium length, erect hairs on ventral surfaces. Gaster with few short, erect hairs lining apical segments dorsally, more abundant, longer hairs on gastral venter. Very short, appressed, mostly white pubescence on dorsum of gaster; pubescence virtually absent from rest of dorsal body surfaces.

Colour. Holotype and associated queen black, with mandibular masticatory border, condylae and apical segments of funiculi medium to dark reddish-brown. Paratypes generally a shade lighter with legs, including coxae, and gaster dark to very dark reddish-brown.

Queen. Dimensions: TL c. 8.26; HL 2.00; HW 1.68; CI 84; SL 2.18; SI 130; PW 1.56; MTL 2.53 (1 measured).

Apart from sexual characters and larger size, closely resembling worker except: pronotal humeri armed with blunt, but distinct teeth; mesoscutum with virtually flat dorsum; lateral margins rather strongly converging anteriorly, forming narrowly rounded anterior margin; median line short; mesoscutellum marginally elevated above dorsal plane of mesoscutum. Propodeum armed

with strong, relatively short, upturned spines; petiolar spines subequal, shorter than in worker. Sculpturation and colour virtually as in holotype worker.

Males and immature stages unknown.

REMARKS. *Polyrhachis incognita* can be distinguished from the other Sulawesian *Myrmothrinax* species (except *P. imitator*), by the deep, 'V'-shaped median emargination of the anterior clypeal margin and its large size and mostly black head and mesosoma. It differs from *P. imitator* by its virtually flat pronotal dorsum, somewhat longer antennal scapes (SL >2.00 versus SL <2.00 in *P. imitator*), distinctly shorter, wide-based, upturned propodeal spines and generally darker body. The two non-type specimens collected by Fruhstorfer compare well with the holotype and I consider them conspecific. Both bear identification tags in Mayr's handwriting as indicated in the above notes on *P. javanica*.

81. Polyrhachis trispinosa Fr. Smith, 1861 (FIG. 12E-F)

Polyrhachis trispinosus Fr. Smith, 1861: 40, pl. 1, fig. 11. Holotype queen. Type locality: INDONESIA, SULAWESI, Tondano (A.R. Wallace), OXUM (examined).

MATERIAL. SULAWESI TENGAH: Lore Lindu NP, Toro, Gn. Kalabui, 950m, 20.iv.2005, nat. for., fog. (M.M. Bos #6) (w, q); ditto, 815m, 19.iv.2005, cacao agrof., fog. (M.M. Bos) (w); ditto, Kauboga, 840m, 4.v.2005, cacao agrof., fog. (M.M. Bos #6, 46) (w); ditto, 15.iv.2005, cacao agrof., fog. (M.M. Bos) (♀); ditto, Watu Bohe, 860m, 25.iv.2005, cacao agrof., fogging (M.M. Bos) (♀).

The worker caste of the species was previously unknown and is described below.

DESCRIPTION. *Worker*. Dimensions: TL c. 6.45-7.66; HL 1.56-1.81; HW 1.22-1.43; CI 78-80; SL 1.96-2.18; SI 149-163; PW 0.84-0.90; MTL 2.15-2.59 (8 measured).

Anterior clypeal margin with wide, medially notched truncation, flanked by acute teeth. Clypeus with blunt median carina that is less distinct anteriorly; clypeus weakly convex in profile, narrowly rounding into moderately impressed basal margin. Frontal triangle poorly indicated. Frontal carinae sinuate with margins weakly and narrowly raised; central area relatively wide, weakly raised medially with shallowly impressed frontal furrow. Sides of head in front of eyes converging into mandibular bases in almost straight line; behind eyes sides broadly rounding into convex occipital margin. Eyes weakly convex, in full face view exceeding lateral cephalic outline. Ocelli lacking, positions indicated by shallow pits in cephalic sculpture. Mesosomal dorsum laterally marginate, rather narrow and slender. Pronotal dorsum with shallow, longitudinal median depression; humeri subangular; promesonotal suture distinct. Mesonotal dorsum with posteriorly raised lateral margins; metanotal groove distinct. Propodeal dorsum longer than wide with lateral margins terminating posteriorly in upturned, acute teeth; propodeal dorsum descending into oblique declivity in medially uninterrupted line. Petiole relatively low, with anterior face widely rounding onto dorsum; posterior face almost straight; dorsum of petiole armed with three spines; lateral pair longer and acute, somewhat dorsolaterally and weakly posteriorly directed; middle spine very short, broad-based and tooth-like, rudimentary in some specimens; position of middle spine variable, situated well behind lateral spines and clearly visible in side view in most specimens but situated more anteriorly and virtually hidden by lateral spines in some specimens. Anterior face of first gastral segment flat, widely rounding onto dorsum.

Mandibles very shallowly, finely longitudinally reticulate. Head, mesosoma and petiole very closely, mostly irregularly reticulate-punctate with sculpturation slightly more coarse on sides of mesosoma. Gaster very finely shagreened, rather polished.

Mandibles with a few, rather short, mostly erect, yellowish-golden hairs at masticatory borders and extremely short, closely appressed hairs towards bases. Anterior clypeal margin with a fringe of short setae lining margin medially and laterally. Clypeus with numerous, relatively long, erect hairs and a few pairs of somewhat shorter erect hairs lining frontal carinae. Anterior and posterior faces of fore coxae with a few, relatively long hairs; mid and hind coxae with a few shorter erect hairs ventrally. Femora with a few, medium length, erect hairs on ventral surfaces. Gaster with a few short, erect hairs along apical segments dorsally; more abundant, longer hairs on gastral venter. Extremely short, closely appressed, silvery or pale golden pubescence very scarcely distributed over all body surfaces, a little more abundant on dorsum of first gastral segment.

Colour. Mostly black or very dark reddish-brown; mandibles dark reddish-brown with teeth black and narrow yellowish band at masticatory borders; clypeus and gastral segments blotched dark reddish-brown; basal funicular and tarsal

segments black with subsequent segments progresively lighter; five apical segments of funiculi and terminal segments of tarsi, including claws, very light yellow.

Queen. Dimensions (holotype queen cited first, compared queen second, 3 *microgynous* queens last): TL 9.88, 9.88, 7.56-7.81; HL 2.21, 2.15, 1.72-1.78; HW 1.72, 1.72, 1.34-1.40; CI 78, 80, 77-80; SL 2.62, 2.71, 2.12-2.18; SI 152, 157, 156-158; PW 1.81, 1.78, 1.50-1.62; MTL 3.18, 3.12; 2.37-2.43.

Queen very similar to worker with usual differences indicating caste; mesosoma rather slender as in worker; configuration of petiolar spines indentical to worker with lateral spines short and acute and median spine very short or rudimentary.

REMARKS. The holotype queen of *P. trispinosa* (OXUM) is undoubtedly conspecific with a queen collected by M.M. Bos at Lore Lindu National Park. Bos also collected a short series of distinctly smaller queens that also closely match the holotype but have proportionally wider pronotal dorsums and more widely rounded anterior margins of the mesoscutum. However, the smaller queens share the characteristic configuration of the petiolar spines found in the holotype, and I consider them *microgynous* queens of *P. trispinosa*.

The workers of *P. trispinosa* closely resemble those of *P. subtridens* Emery, 1900, from Mentawei I. and *P. solivaga* Menozzi,1926, from the Philippines. I have compared the syntypes and other specimens of all three species and found them very similar. All feature a shallow, longitudinal, median depression on the pronotal dorsum and an almost identical configuration of the petiolar spines, featuring rather short lateral spines and a rudimentary middle spine. They differ in several characters, including the width of pronotal dorsum, the length of the mesosoma and the colour of the body. In *P. subtridens* and *P. solivaga* the pronotal dorsum is wider with its sides rounded and the median depression rather distinct. The propodeal declivity is steeply oblique and the lateral petiolar spines range from short to rudimentary within single populations. In contrast, the narrower pronotal dorsum in *P. trispinosa* specimens has sides ranging from weakly rounded to almost straight and has a less distinct median depression. In addition, the mesosoma of *P. trispinosa* is distinctly more slender and longer with the propodeal declivity less steeply oblique. The colour of the body in *P. subtridens* and *P. solivaga* specimens is generally medium reddish-brown, while it is distinctly darker, virtually black, in most *P. trispinosa* specimens.

Polyrhachis thrinax species-group

KEY TO *THRINAX*-GROUP SPECIES (based on workers)

1. Frontal carinae distinctly elevated; propodeal spines upturned; lateral petiolar spines shorter than middle spine, but always present; body generally very dark reddish-brown (in copal) ..... *cincta* Viehmeyer

   Frontal carinae with margins only narrowly and weakly elevated; propodeal spines horizontal; lateral petiolar spines very short, often rudimentary; body generally very light to medium yellowish- or reddish-brown ..... *unicuspis* Emery

82. Polyrhachis cincta Viehmeyer, 1913

Polyrhachis dahli var. *cincta* Viehmeyer, 1913: 149. Syntype workers. Type locality: INDONESIA, SULAWESI (in copal), SNSD, MNHU (examined).

Polyrhachis cincta Viehmeyer. Kohout, 1998: 510.

REMARKS. The two syntype workers from copal are the only known specimens of *P. cincta*. The differences between this species and the very similar *P. dahlii* Forel and *P. queenslandica* Emery were discussed by Kohout (1998).

83. Polyrhachis unicuspis Emery, 1898 (FIG. 12G-H)

Polyrhachis unicuspis Emery, 1898: 240, fig. 13. Holotype worker. Type locality: INDONESIA, SULAWESI, Toli-Toli (H. Fruhstorfer), MCSN (examined).

MATERIAL. SULAWESI: Ayermaidi (W.M.Mann) (w). SULAWESI TENGAH: Lore Lindu NP, Toro, Kauboga, 840m, 4.v.2005, cacao agof., fog. (M.M. Bos #46) (w); ditto, Gn. Kalabui, 950m, 20.iv.2005, nat. for., fog. (M.M. Bos) (w); ditto, Toro, Foot of Gn. Kamanua, 845m, 28.iv.2005, cacao agrof., fog. (M.M. Bos) (♀); ditto, Toro, Baloli, 835m, 14.iv.2005, cacao agrof., fog. (M.M. Bos) (♀); ditto, Toro, Kaha, 920m, 15.iv.2005, cacao agrof., fog. (M.M. Bos) (♀); ditto, Toro, Kauboga, 840m, 4.v.2005, cacao agrof., fog. (M.M. Bos) (♀).

REMARKS. *Polyrhachis unicuspis* is characterised by a relatively long middle petiolar spine and rudimentary lateral spines. However, in the available queens, the lateral spines are developed as short, but distinct and acute spines. This is apparently a rare species and until very recently I had seen only the holotype and a single

specimen collected in 1937 by W.M. Mann at Ayermaidi (= Air Madidi).

Subgenus **Polyrhachis** Fr. Smith, 1857

84. **Polyrhachis erosispina** Emery, 1900

Polyrhachis bellicosa var. *erosispina* Emery, 1900: 713 (footnote). Syntype workers. Original localities: NEW GUINEA, Ramoi (O. Beccari); INDONESIA, SULAWESI, Kandari (O. Beccari), MCSN (examined).

Polyrhachis erosispina Emery. Kohout, 1988: 419. Lectotype and paralectotypes designated.

MATERIAL. SULAWESI UTARA: Mt Klabat, Air Madidi slope, 400-600m, wet for., 13-19.vi.1972 (W.L. Brown) (w). SULAWESI TENGGARA: nr Sagona, Base Camp, I Watuwila, c. 200m, 15.x.-5.xi.1989 (Malaise trap) (C.van Achterberg) (w); 1-2km E of Wolasi, 42km S of Kendari, c. 350m, rf, 13-14.vii.1972 (W.L. Brown) (w). SULAWESI SELATAN, Cagar Alam Karaenta, Kabupaten Maros, c. 265-315m, iii.1996 (B. Gobin) (w).

REMARKS. *Polyrhachis erosispina* is very similar to *P. bellicosa* Fr. Smith, 1859, from Indonesia and New Guinea and the main differences between them were discussed in detail by Kohout (1988a: 418-422). Comparison of the above listed workers with the paralectotype of *P. erosispina* collected by O. Beccari proves them undoubtedly conspecific.

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